A Study for the Improvement, Restoration, and Protection of

Lake Bruce

Fulton and Pulaski Counties, Indiana

S[illegible] To:

Earth·Source Inc

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Lake Bruce . . .

Fulton and Pulaski Counties, Indiana

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Acknowledgments/Credits

Many individuals from various agencies, interests, and expertise contributed to the preparation of this report.

The local entity which provided strong efforts in communication, information, and scheduling meetings is the Lake Bruce Association Inc. For assistance with the lake sampling, providing boat for lake sampling and their outstanding leadership, Bob and Bette Miller. Bob Hughes for use of his boat, and Barbara Klinck and Shirley Kanzler for hosting various meetings, and the Kewanna/Union Township Fire Department for providing a meeting place.

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Indiana State agencies include the Department of Environmental Management; Department of Natural Resources, Divisions of Soil Conservation, Nature Preserves, Water, Fish and Wildlife, and the Staff and Associates of Earth Source Inc., William Eviston, ASLA, Principal; and Eric Ellingson, Project Manager; Thomas Crisman, Ph.D, Associate; Michael Gensic, P.E.; Nathan Simons, Landscape Architect; Timothy Karasek; Ulrike Crisman; and Linda Eviston.

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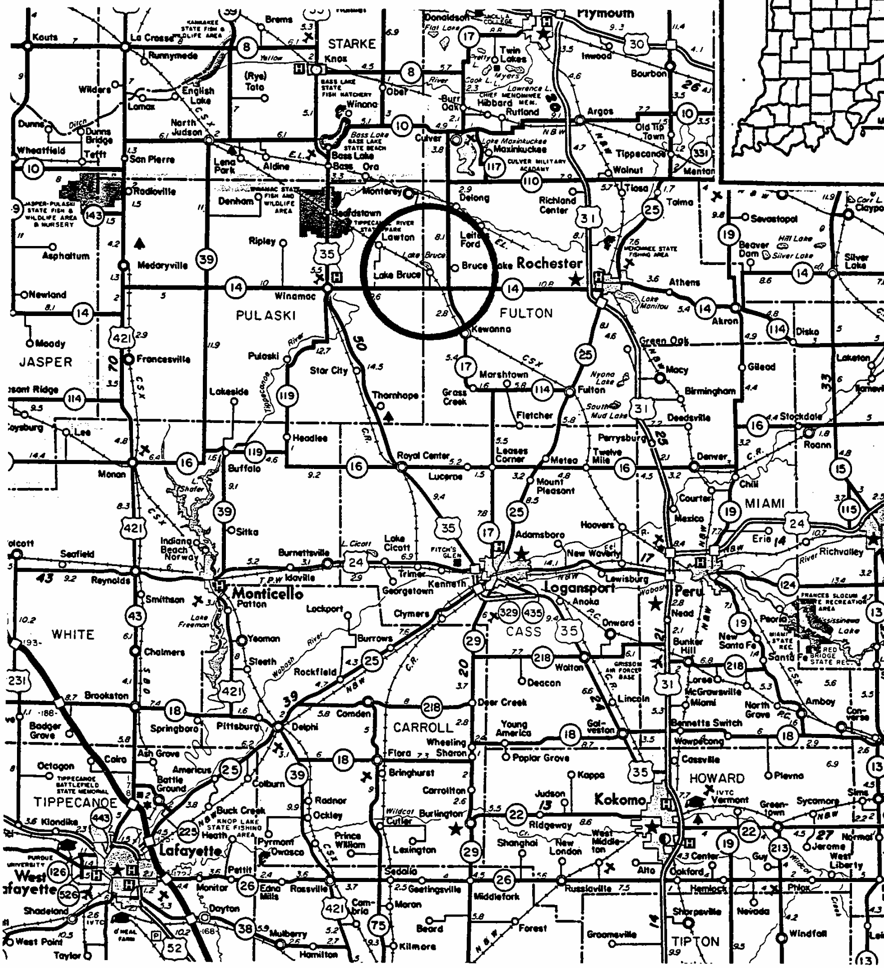
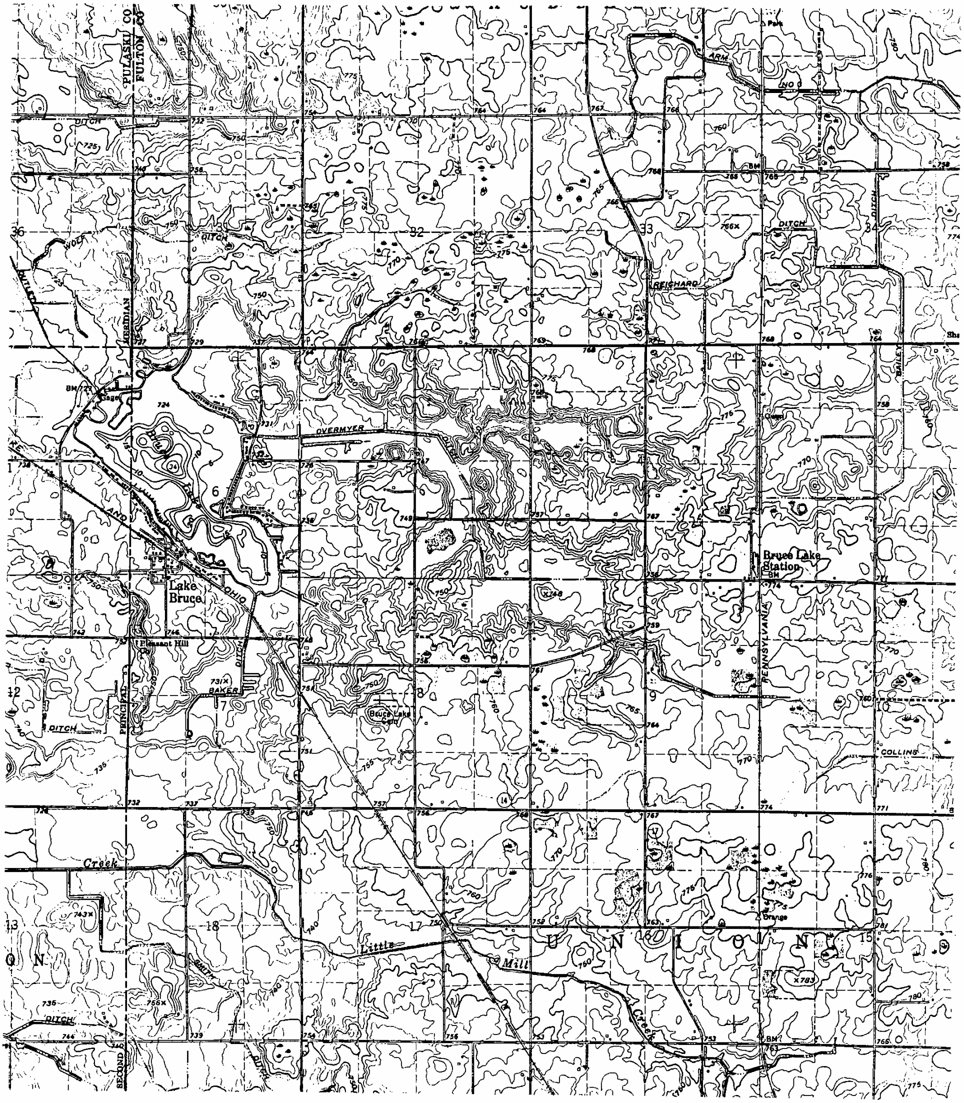


Regional Location Map


PULASKI CO
FULTON CO
DITCH
OVERMYER
REISHARD
Lake
Bruce
Pleasant Hill
BAKER
Bruce Lake Station
PENNSYLVANIA
COLLINS
BAILEY
Creek
Little
Mill
Creek
U N I O N
Orange
MERIDIAN
PRINCIPAL
SECOND

Area Map

Executive Summary

EXECUTIVE SUMMARY

Lake Bruce is a eutrophic lake in Fulton County, Indiana composed of two basins. Historical data suggest that eutrophication has accelerated in the lake since at least the late 1960's when aquatic weed problems and algal blooms were noted during summer. Currently, the lake has serious weed problems in waters less than 5 feet deep, most of which are attributed to the exotic species Eurasian watermilfoil. Algal blooms dominated by blue-green algae are common during summer and the fishery is dominated on a numerical basis by the rough fish gizzard shad.

The principal contributing factor for the eutrophication of Lake Bruce has been identified as nutrients and sediments from watershed sources and delivered by ditches into the lake. Stream borne sediment has been responsible for pronounced basin infilling of nearshore areas with some shallow depth contours increasing up to 42% in aerial extent since 1955.

It is recommended that while aquatic weed beds be left intact at the mouths of inlet ditches to serve as nutrient and sediment traps, cost effective weed control for Lake Bruce can be achieved through winter lowering of lake level by five feet. Such an action will help consolidate and oxidize nearshore sediments and will freeze reproductive structures and roots of aquatic weeds. Although species specific responses to drawdown have been noted, control of the problem species in Lake Bruce should be effective. Potential detrimental consequences of drawdown should be considered as part of any management plan including possible increased phytoplankton, winter fish kills and increased predation on young fish, It is recommended that implementation of such a program of water level fluctuation be monitored by the Indiana Department of Natural resources.

If drawdown is used as a macrophyte control at Lake Bruce, it is recommended that mixed species assemblage of emergent macrophytes be maintained or planted at all stream mouths to act as a nutrient and sediment filter. Emergent vegetation should prove resistant to additional winter drawdowns, thus minimizing the negative impact on stream "kidney".

It is suggested that successful lake management will be hindered until watershed sediment and nutrient loading to the lake are reduced drastically. For this reason, priority should be given to one or more of the major constructed options and/or land treatment of critical erosion areas, prior to any significant aquatic weed control programs.

Lake Bruce 1.

LAKE BRUCE

Introduction

Lake Bruce (figure page ii), Fulton-Pulaski County, is a 245 acre lake with a maximum and mean depth of 34 feet (1955) and 14 feet, respectively. Legal lake level is 723.69 feet and is controlled by a concrete dam at the outlet into Lake Bruce Outlet that drains directly into the Tippecanoe River. Lake Bruce has three main inlets (figure page iii): Baker Ditch (south), Overmyer Ditch (east) and Frasa Ditch (north).

The present study was initiated because of lake residents concerns regarding excessive submergent weed growth, a reduced quality recreational fishery, and observation of siltation in the lake associated with delivery of erosion products from the watershed especially during early spring rains.

The current chapter is designed to define the current water quality of Lake Bruce and to determine whether current values represent a marked decline in water quality within the historical past. Accordingly, it has been separated into three subsections. The first section presents a detailed examination of the historical database on the water quality for Lake Bruce. The second section summarizes the water quality analyses conducted as part of the present study and compares values to earlier studies. The third and final section details our sediment studies at Lake Bruce where we were interested in learning the extent of basin infilling in the historical past as well as changes in phosphorus loading to the lake. Management implications of our analysis of past and current water quality will be discussed later in this report.

Historical Water Quality

Database

A total of 23 separate studies were conducted at Lake Bruce between 1955 and 1988 for which data were available (Table 1). The United States Geological Survey constructed a bathymetric map for Lake Bruce in 1955, but collection of water quality data on the lake did not begin until 1967. The Indiana Department of Natural Resources surveyed the fish community 10 times after 1967 and in several of these surveys included data on water chemistry and macrophytes. The Indiana State Board of Health estimated bacterial numbers in the lake 4 times and visited the lake once in the

Table 1. Chronology of Investigations at Lake Bruce

1955	United States Geological Survey. Construction of bathymetric map for Lake Bruce.
1967	Indiana State Board of Health. Bacteriological investigation at 1 sampling station.
1967	Indiana Department of Natural Resources. Survey of fish community, physical/chemical parameters, macrophyte composition.
1968	Indiana State Board of Health. Bacteriological investigation at 17 sampling stations.
1969	Indiana State Board of Health. Bacteriological investigation at 17 sampling stations.
1970	Indiana Department of Natural Resources. Survey of fish community, physical/chemical parameters, macrophyte composition.
1973	Indiana Department of Natural Resources. Survey of fish community and physical/chemical parameters.
1974	Indiana Department of Natural Resources. Selective chemical removal of gizzard shad and stocking of 19,265 largemouth bass fingerlings.
1975	Indiana Department of Natural Resources. Survey of fish community, physical/chemical parameters, macrophyte composition.
1975	Indiana State Board of Health. Survey of several physical/chemical parameters and algal abundance and composition for construction of BonHomme eutrophication index.
1976	Lake Bruce Association. Dye testing of septic systems along shore.
1976	Indiana Department of Natural Resources. Survey of fish community, physical/chemical parameters, macrophyte composition.
1977	Indiana Department of Natural Resources. Survey of fish community and physical/chemical parameters.
1977	Lake Bruce Association. Dye testing of septic systems along shore.

1978 <u>Indiana Department of Natural Resources</u>. Survey of fish community and physical/chemical parameters.

1978 <u>Indiana Department of Natural Resources</u>. Stocking of 8,483 northern pike 3-4 inches long.

1978 <u>Lake Bruce Association</u>. Dye testing of septic systems along shore.

1979 <u>Indiana Department of Natural Resources</u>. Survey of fish community.

1980 <u>Indiana Department of Natural Resources</u>. Survey of fish community and physical/chemical parameters.

1982 <u>Indiana Department of Natural Resources</u>. Survey of fish community and physical/chemical parameters.

1983 <u>Fulton County Soil & Water Conservation District, Fulton County Drainage Board, and Lake Bruce Association</u>. Development of watershed protection plan.

1985 <u>Indiana State Board of Health</u>. Bacteriological investigation at 5 sampling stations.

1988 <u>Indiana University</u>. Single sampling for chemical and biological parameters needed for construction of BonHomme eutrophication index.

mid-1970's to collect water chemistry and select biological data for construction of a eutrophication index for classifying the lake relative to other lakes in the state. The Lake Bruce Association conducted dye testing of septic systems at shoreline residences in 1976, 1977, and 1979, and a watershed protection plan was developed as part of a joint cooperative effort of several agencies in 1983. The most recent investigation has been the 1988 survey of the lake by Indiana University for the Indiana Department of Environmental Management. No other data were found in the files of state and federal agencies or as research projects conducted by universities of the state.

Physical/Chemical Parameters

A total of seven physical and chemical parameters have been measured at Lake Bruce at a frequent enough interval to be useful in delineating historical trends (Table 2). Secchi depth transparency is a good estimator of either inorganic turbidity from suspended sediment or algal biomass. As Secchi values have historically been recorded during summer, it is likely that they reflect algal biomass rather than suspended inorganic sediment. It is expected that Secchi values should get progressively lower throughout summer as algal biomass builds in response to steadily increasing temperature. Thus, it is only valid to make interyear comparisons for individual months (Table 2, Figure 1). Secchi values for May 1989 (North 9.75 feet, South 10.58 feet) were the highest transparency readings ever recorded including the only other May reading (2.0 feet in 1978). Unfortunately all other previous readings were collected during June-August and thus can not be used for establishing intramonthly historical trends. It is normal for May values in a lake to be higher than during summer because algal populations are generally lower in late spring. The July readings for 1989 (North 5.92 feet, South 5.71) were greater, however, than recorded for any midsummer month in the database. Finally, the mean for the two sampling dates of 1989 (Figure 1) was greater than values recorded on all previous occasions. As will be discussed later in this chapter, this recent increase in water clarity may not reflect an improvement in water quality, but may result from expansion of submergent weed growth to a point that such plants can effectively compete with algae for nutrients in the water column. The end result would be fewer algae suspended in the water column and clearer water.

As with Secchi disc transparency, mean water column dissolved oxygen values are expected to decrease throughout the summer in response to increasing temperature and algal production (Table 2). A majority of previous estimates of midsummer mean oxygen values in the water column of Lake Bruce historically remained below 5.0 mg/L suggesting fairly

Table 2. Historical Changes in Physical and Chemical Parameters at Lake Bruce for the Period 1967-1988.

Historical Data		August 1967	June 1970	June 1973	June 1975	August 1975	June 1976	August 1977	May 1978	August 1980	June 1982	August 1988
Secchi	feet	1.4	2	2	3.5	2.5	2.5	2.5	2	2.5	3.5	1.6
Mean Dissolved Oxygen	mg/L	3.2	3.31	3.28	6.85	4.31	4.37	6.02	6.98	4.77	4.74	2.57
Conductivity	umhos/cm											320
Alkalinity	mg/L as CaCO3	169	197	195	187		229	119	136		205	179
pH		9	7.2	7	7.7		8.3	8.8	6.8		8.8	7.5
Ca	mg/L		98		148		136					
Fe	mg/L		0.2									
K	mg/L		3									
Mg	mg/L		100									
Mn	mg/L		0.03									
Na	mg/L		5									
Cl	mg/L		12									
SO4	mg/L		23									
Total Phosphorus	mg/L		0.2		0.06	0.12	0.03					0.105
Ortho Phosphorus	mg/L					0.09						0.03
Nitrate-N	mg/L		0.3			0.1	0.1					0.8
Ammonia-Nitrogen	mg/L					2.2						2.8
Total Kjeldahl N	mg/L											1.4
Nitrite-Nitrate	mg/L				2.1							
Chlorophyll	mg/m3											

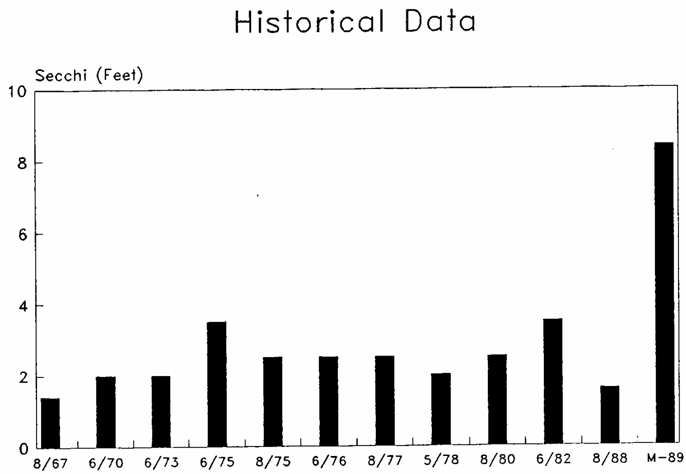


Figure 1. Historical Secchi Disk Readings in Lake Bruce for the Period 1967-1989. M-89 represents the mean of May and July 1989.

eutrophic conditions. While mean water column dissolved oxygen in the north basin of Lake Bruce (3.91) during July 1989 was consistent with previous midsummer estimates, the higher value for the south basin (7.00) was the maximum reported for the lake during midsummer and likely attributable to photosynethsis by aquatic weeds. The historical data suggest that deep water deoxygenation during summer has characterized Lake Bruce for at least the past 22 years.

A good measure of the extent of eutrophication is provided by the extent of water column anoxia in mid summer (Table 3). The historical data suggest that the water column of Lake Bruce by June normally is devoid of oxygen below a depth of 10-15 feet. This zone of oxygen free water appears to be steady throughout summer with little change in its vertical extent. As will be discussed later, the data for 1989 in both the north and south basins of Lake Bruce were consistent with trends established in previous investigations.

Alkalinity, a measure of the carbonate buffering capacity of lakes, did not display a clear historical trend (Table 2, Figure 2). The maximum value for this parameter was reported in 1976 (229 mg/L), while the minimum was reported the following year (119 mg/L). Alkalinity for the two sampling dates of 1989 (Table 9) and the overall mean for 1989 were lower than reported during all previous years with the exception of 1977 and 1978.

Although the remaining physical and chemical parameters were sampled too infrequently to provide any historical perspective (Table 2), examination of the limited database for total phosphorus suggested a progressive increase in water column values from the mid 1970's to 1989 (Figure 3). The maximum total phosphorus value reported for Lake Bruce was during 1970. It is likely that phosphorus loading to the lake has not decreased, rather nutrient uptake by the accelerated expansion of submergent macrophytes since the mid 1970's has proven effective at depleting water column phosphorus levels. No previous survey attempted to evaluate whether photosynthesis in Lake Bruce was nitrogen or phosphorus limited.

Microbiology

Mr Wesley Burden of the Fulton County Health Department supplied microbiological data from 4 surveys conducted by the Indiana State Board of Health between 1967 and 1985 (Table 4). Please note that these surveys were meant to identify pollution sources and thus were conducted in the vicinity of suspected violators. Of the 17 stations sampled during both 1968 and 1969, 5 and 4, respectively, exceeded

Table 3. Historical Records of Water Column Anoxia in Lake Bruce, IN

Observation	Initial Depth of Less than 1 mg/L Dissolved Oxygen
April:	
1980	25 feet
May:	
1978	DO to bottom
1989	DO to bottom
June:	
1970	15 feet
1973	10 feet
1975	DO to bottom
1976	15 feet
1982	15 feet
July:	
1989	9 feet
August:	
1967	10 feet
1975	15 feet
1977	DO to bottom
1988	9 feet

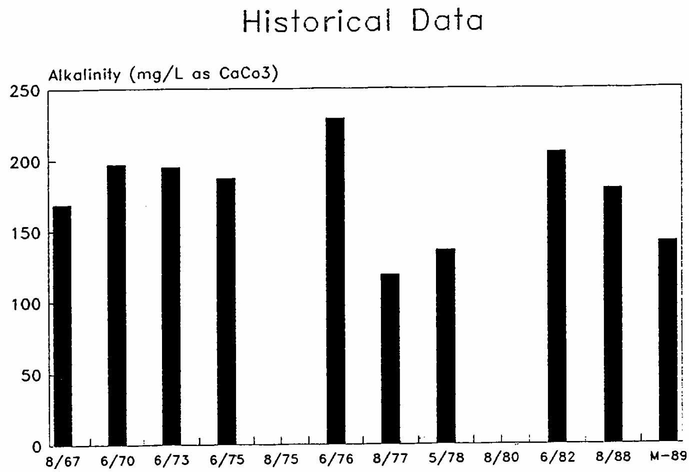


Figure 2. Historical Alkalinity Readings in Lake Bruce for the Period 1967-1989. M-89 represents the mean of May and July 1989.

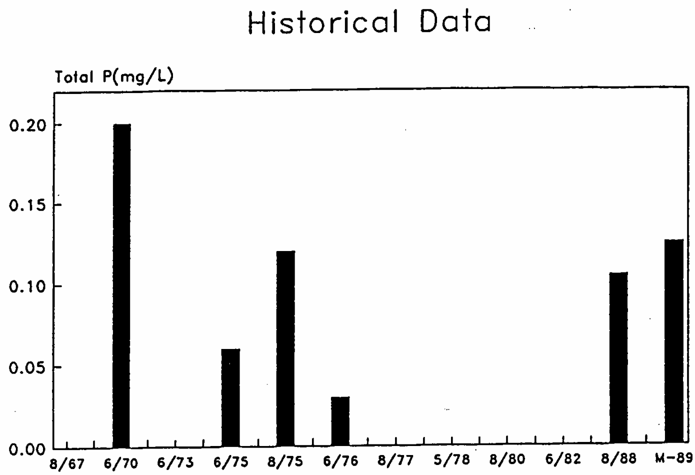


Figure 3. Historical Total Phosphorus Concentrations in Lake Bruce for the Period 1970-1989. M-89 represents the mean of May and July 1989.

Table 4. Compilation of Past Microbiological Testing at Lake Bruce

Date	# Stations Sampled	Coliform Bacteria	mpn/100mL		mpn/100mL	Fecal Coliform	mpn/100 mL	Fecal Strep/100 mL	
		Mean	Maximum	# Stations >1000/100 mL	# Stations >1000/100 mL	Maximum	# Stations >400/100 mL	Maximum	# Station >100/mL
19 April 1967	1		<2						
23 July 1968	17	6030	90000	5	5				
1 July 1969	17	794	4600	4	4	45000	1		
4 September 1985	5					28	0		

state standards for total coliform bacteria levels expressed as most probable numbers (mpn). None of the stations sampled during 1985, however, exceeded state standards. Dye testing of shoreline septic systems by the Lake Bruce Association during the mid-late 1970's demonstrated many faulty systems that were leaking into the lake. The above data as well as notes in the files of the Fulton County Health Department suggest that improperly functioning sewage disposal systems have been an important nutrient loader to Lake Bruce and a factor in its eutrophication.

Phytoplankton

Phytoplankton samples have been collected only once as part of the Indiana State Board of Health survey in the summer of 1975. Although representatives of three algal groups were identified (Table 5), dominant algae in Lake Bruce were green algae (Microspora: 1,700 units/mL in surface waters) and diatoms (Synedra: no individual counts given). Total algal abundance was 3,000 units/mL in surface waters. With the exception of Microspora, the abundance of individual algal taxa was not given. As this information came from unpublished notes from ISBH files and no details were given on whether algal counts were based on the abundance of cells or "individuals", we have used the term "units" as an undefined expression. During their August 1967 survey, the DNR observed an algal bloom that gave the water a "pea green" appearance and noted that according to residents, such blooms were common throughout summer in most years.

Macrophytes

The macrophyte (aquatic weed) community was examined four times in conjunction with Indiana Department of Natural Resources fish surveys conducted between 1967 and 1976. The greatest diversity of taxa recorded has always been for the submergent community (Table 6). The dominant plants in Lake Bruce historically have been the alga chara and coontail. The remaining communities, emergents, floating-leaved, and free floating, have been represented by three, two, and one taxa, respectively. It is interesting to note that the species composition of the entire weed community appears to have changed little between 1967 and 1976.

The DNR survey of 1967 identified the macroalga Chara as the dominant submergent plant in Lake Bruce and noted that heavy infestations of this plant were found in "northern and eastern shallows" of the lake. It was suggested that a chemical control program be initiated using copper sulphate. Submergent weeds were abundant from the shore to a depth of five feet during June 1970, prompting

Table 5. Phytoplankton Composition of Lake Bruce August 1975

Algal Group	Genus
Diatoms	Cyclotella
	Fragilaria
	Synedra
Greens	Chlorella
	Crucigenia
	Microspora
	Pediastrum
	Scenedesmus
Blue-Greens	Lyngbya

Table 6. Species Composition of the Macrophyte Community of Lake Bruce for the Period 1967-1976.

Species	Common Name	1967	1970	1975	1976
SUBMERGENTS:					
Ceratophyllum demersum	coontail	x	x	x	x
Chara spp.	chara	x	x	x	x
Najas flexilis	bushy pondweed		x	x	x
Potomogeton crispus	curly pondweed		x	x	x
Potomogeton pectinatus	sago pondweed		x	x	x
Vallisneria americana	eelgrass		x	x	x
EMERGENTS:					
Sagittaria latifolia	arrowhead		x	x	x
Scirpus americanus	bulrush		x	x	x
Typha latifolia	common cattail		x	x	x
FLOATING LEAVED:					
Nuphar advena	spatterdock	x	x	x	x
Nymphaea tuberosa	waterlily	x	x	x	x
FREE-FLOATING:					
Lemna spp.	duckweed		x	x	x

the DNR to suggest that a chemical control company be retained because of the aerial extent of the weed problem. A similar conclusion was reached as a result following the 1973 and 1975 DNR surveys. Subsequent DNR surveys reported abundant vegetation to a depth of five feet and suggested control of excessive vegetation.

Fish

The Indiana Department of Natural Resources surveyed the fish community of Lake Bruce ten times between 1967 and 1982. For the following discussion, it must be remembered that historical changes in the fish community are considered indicative of trends and that interyear differences in the percentage contribution of each taxon reflect to some unknown degree interyear variability in sampling methodology. A listing of the individual species caught and the contribution of each to total fish abundance caught during DNR surveys from 1967-1982 is presented in Table 7. Although a total of 26 taxa have been identified from Lake Bruce, black crappie, bluegill, gizzard shad, golden shiner, and yellow perch have been the dominant taxa for at least the past 22 years. Since at least 1975, rough fish clearly have been the dominant fish on a weight basis (Table 8) especially carp (4-33% of total fish weight), gizzard shad (3-41%), and spotted gar (1-30%). Although bluegill, golden shiner, and yellow perch were numerically important, they contributed only 2-5%, 1-4%, and 1-3%, respectively, of total fish weight in Lake Bruce. The remaining fish taxa have not represented over 10% of total fish weight in the lake since at least 1975.

The growth rate of bluegill and largemouth bass was excellent in 1967, but the population of the latter was considered low. Gizzard shad, the dominant rough fish, was abundant but appeared to have low reproductive success. It was felt that while predator fish were currently able to keep forage and panfish from overpopulating the lake, an increase in the predator population was desirable.

While the overall fishery was considered satisfactory in 1970 with average to above average condition factors and growth rates, two observations were considered note worthy. The largemouth bass population appeared to have decreased markedly since 1967, and young of the year and I+ fish were essentially absent from the population. In addition, the rough fish population (gizzard shad, brown bullhead, carp) had increased by 46% in the three year period. A further decline in the fishery was noted during the 1973 DNR survey including a drop in the relative abundance of bluegill (22% to 5%) between 1970 and 1973 concurrent with a marked increase in that of gizzard shad (4% to 36%). The relative abundance of largemouth bass also declined during the three

Table 7. Importance of Individual Fish Species Expressed as a Percent of Total Fish Abundance for DNR Surveys at Lake Bruce.

	1967	1970	1973	1975	1976	1977	1978	1979	1980	1982
Black Bullhead		0.2						1.5	1.6	
Black Crappie	3.9		15.5	5.7	6.4		5	14.8	3.2	4
Bluegill	30	22.5	5.5	17.3	13.6	9.5	10.3	1	12.9	19
Bowfin	0.3	0.6	<1	0.9	1.3	0.9			0.3	
Brook Silversides	0.3		<1	1						
Brown Bullhead	2.8	11.7	1.9	3.9	3.1	4.8	3.9	2.5	11.3	
Carp	0.8	3.1	<1	1.5	4.2	0.6	2.1		0.6	
Channel Catfish						0.1				
Gizzard Shad	22.5	4.4	36.2	4.6	36.6	38.2	59.8	57.9	50.8	57
Golden Shiner	3.1	14.8	7.1	17.6	5.3	4.4	<1	6.6	0.6	
Grass Pickeral	0.3						<1			
Green Sunfish	0.3		<1							
Lake Chubsucker	5.8	2.1	<1		1.5	0.4	<1			
Largemouth Bass	4.8	1.2	1	4.3	7.4	2.8	1.7	0.5	1.9	
Longear Sunfish				0.2	0.7	0.2	<1			
Longnose Gar		0.6		1		0.2	<1			
Northern Pike								4.1	0.6	
Pumpkinseed	10.5	3.1	1.7	3.4	1.3	3.3	1		1	
Redear	1.4									
Shortnose Gar						0.1				
Spotted Gar	0.6	4.9	4.2	9.6	7.7	5.2	1	4.1	4.5	
Warmouth	3.7	0.8	<1	0.9	1.5	1.9	<1	0.5	2.2	
White Crappie	1.5	18.1	5.7	13.4	1.1	17.1	4.4	1.5	2.9	6
White Sucker		2.4	4	3.8	1.8	0.8	1.2		3.8	
Yellow Bullhead	0.7	2.1		0.2	0.2		<1	2.1	0.3	
Yellow Perch	6.7	7.5	15.3	10.8	5	10.3	8	2.5	1	5

Table 8. Importance of Individual Fish Species Expressed as a Percent of Total Fish Weight for DNR Surveys at Lake Bruce.

	1975	1976	1977	1978
Black Bullhead				
Black Crappie	1.6	1.3		1.4
Bluegill	5.5	2.7	2.9	2.3
Brook Silverside	1.3			
Brown Bullhead	3.3	4.2	7.6	4.7
Bowfin	5.1	8.8	9.2	
Carp	13.4	16.3	4.8	33.3
Channel Catfish			0.2	
Gizzard Shad	3.6	17.3	29.9	41.4
Golden Shiner	4.0	1.6	1.4	<1
Grass Pickeral				<1
Lake Chubsucker		0.5	0.3	<1
Largemouth Bass	6.6	8.8	5.3	2.9
Longear Sunfish	0.1	0.1	0.1	<1
Longnose Gar	8.2		1.2	<1
Northern Pike				
Pumpkinseed	1.8	0.2	0.8	<1
Quillback				
Redear				
Shortnose Gar			0.9	
Spotted Gar	30.8	29.6	24.6	<1
Spotted Sucker				
Warmouth	0.2	0.4	0.7	<1
White Crappie	3.5	0.5	4.1	1.9
White Sucker	9.1	6.9	4.2	4.9
Yellow Bullhead	0.3	0.1		<1
Yellow Perch	3.0	0.8	2.0	2.0

year period. The DNR suggested that a partial eradication program utilizing the chemical antimycin be employed to reduce populations of gizzard shad, crappie, and yellow perch. While it was felt that such a program should have little effect on either bluegill or largemouth bass, it was suggested that chemical control be followed by stocking with largemouth bass to increase predation on small gizzard shad.

A selective fish eradication treatment using antimycin was implemented during fall of 1974, after which 19,265 largemouth bass fingerlings were stocked. During 1975, the DNR noted that there was an improvement in the percentage of the bluegill population considered catchable, and the relative abundance of the gizzard shad population was lower than in 1973. The DNR suggested stocking Lake Bruce with northern pike fingerlings to supplement the predator base on gizzard shad, golden shiners, and yellow perch. The gizzard shad population showed signs of recovery by 1976, and the DNR suggested an additional chemical eradication/bass stocking treatment as well as imposition of a 14 inch catch minimum on largemouth bass.

By 1977, the gizzard shad population appeared to have recovered from the 1974 eradication program. Although the numerical abundance appeared relatively constant, the weight of shad had tripled suggesting that the individuals surviving the eradication program had now grown to sufficient size to be relatively immune from predation. A second eradication program was suggested for the following year.

A total of 8,483 northern pike 3-4 inches long were stocked in Lake Bruce on 2 June 1978 in order to enhance the predator base for the expanding gizzard shad population. Although gizzard shad remained dominant, subsequent DNR surveys in 1979, 1980, and 1982 suggested that the survival and growth of northern pike in Lake Bruce appeared good. The latter survey did suggest, however, that additional stocking of northern pike was warranted.

Changes in the percentage contribution of select species to total fish abundance as recorded in DNR surveys of 1967-1982 are summarized in Figure 4. Largemouth bass has consistently comprised less than 10% of total fish abundance for at least the past 22 years. Bass populations increased markedly following the 1974 selective eradication of shad and reached maximum representation in 1976. As shad populations rebounded in the late 1970's, the percentage contribution of largemouth bass to total fish abundance declined progressively.

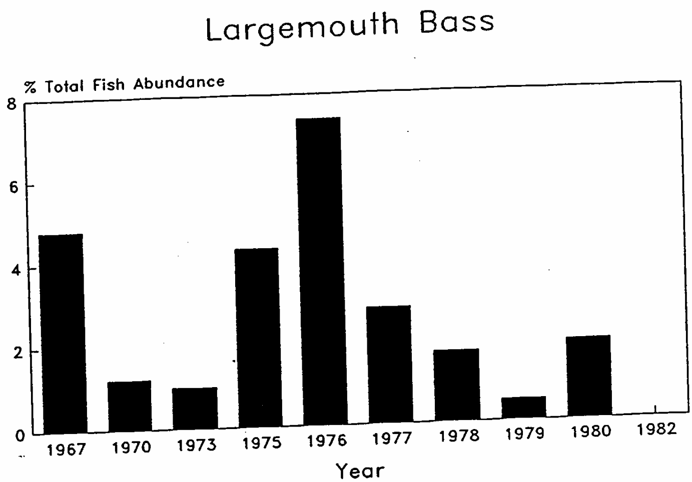
Bluegill populations declined throughout the late 1960's and early 1970's, but were markedly higher in 1975, the first year following selective fish eradication. With the exception of 1979, the contribution of this species to total fish abundance remained at 9-19% for the period 1975-1982.

The most worrisome fishery change in Lake Bruce has been the expansion of gizzard shad post 1970 (Figure 4). With the exception of 1975, the year following a chemical eradication program, the percentage contribution of gizzard shad to total fish abundance increased progressively from 1970 to 1978 with the greatest incremental increase occuring between 1970 and 1973. Since 1978, shad dominance appears to have remained relatively constant at 50-60% of total fish abundance. Such shad levels pose potential management problems in that once established, this species promotes phytoplankton dominance by blue-green algae through its differential digestion of other algal taxa, elevated predation on large cladoceran zooplankton, and enhanced nutrient cycling for phytoplankton utilization (Crisman and Kennedy 1982, Crisman and Beaver 1988, 1990). Such a sharp increase in shad suggests that the eutrophication of Lake Bruce increased markedly between 1970 and 1973.

Current Water Quality

Introduction

Water quality parameters were collected during 1989 on 25 May and 6 July. As specified by the contract a sampling station was established in the north basin of Lake Bruce for detailed water chemistry and biology (Figure 5). Although not part of our contractual commitment, we also added a sampling station in the southern basin of the lake (Figure 5), only Secchi disc transparency and oxygen and temperature profiles were developed for this station. Both stations were located in the area of deepest water as close to the center of each basin as possible. Dissolved oxygen and temperature profiles were determined with a YSI oxygen meter, and light transmission was estimated with a Secchi disc and a Licor photometer. Water samples for chemical, bacteriological and chlorophyll analyses were taken from composite samples of the water column where a Kemmerer bottle was used to collect water at each meter of the water column. All analyses were performed in certified laboratories according to EPA techniques (EPA-600/14-79-020, Methods for Chemical Analysis of Water and Wastes, Revised March 1983). Data for physical and chemical parameters for individual basins during the 1989 survey are presented in Table 9.



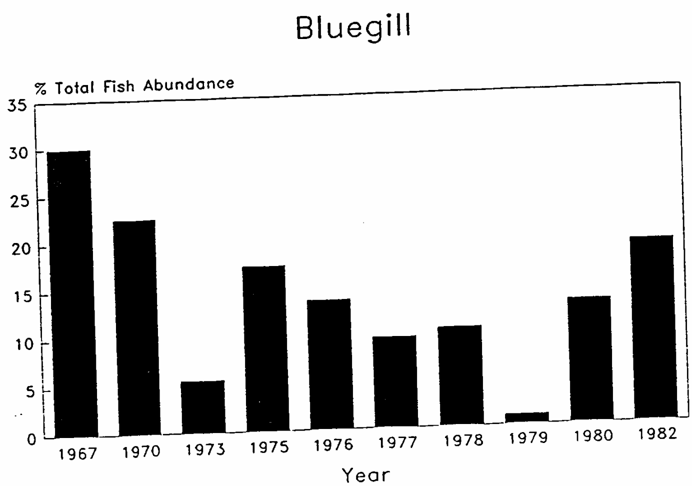
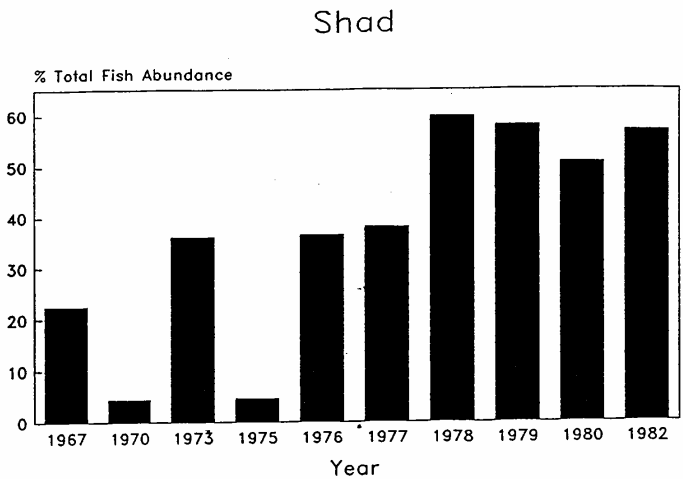


Figure 4. Changes in the Percentage Contribution of Select Species to Total Fish Abundance in Lake Bruce for the Period 1967-1982.



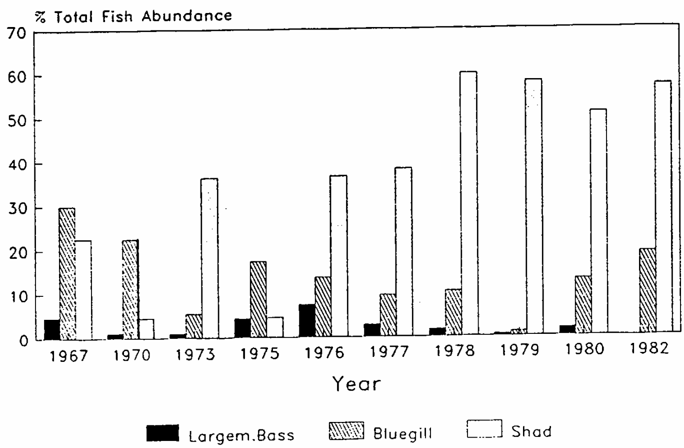


Figure 4. (Continued)

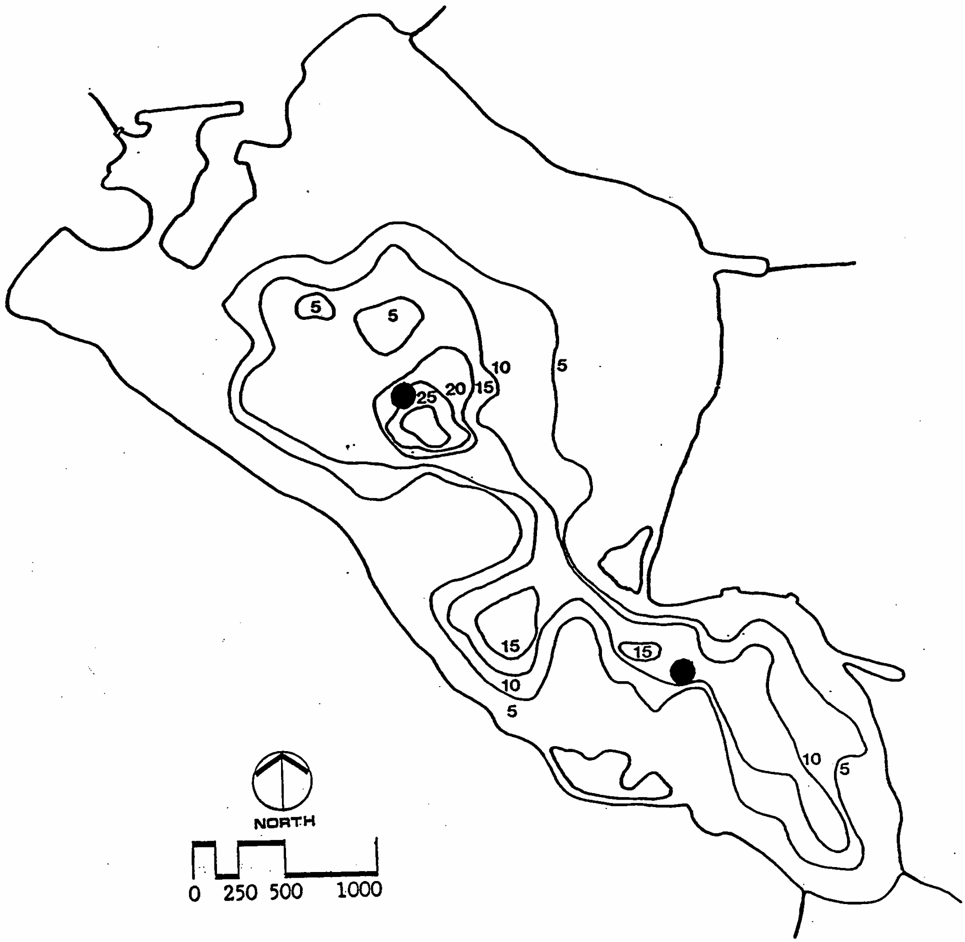


Figure 5. Water Quality Sampling Stations in Lake Bruce for 1989.

Table 9. Physical and Chemical Parameters for the 1989 Survey of Lake Bruce.

		25 May 1989		6 July 1989	
		North	South	North	South
Secchi	feet	9.75	10.58	5.92	5.71
Mean Dissolved Oxygen	mg/L	8.66	10.42	3.91	7
Ammonia	mg/L			0.08	
Total Kjeldahl N	mg/L	4.5		3	
Nitrite-Nitrate	mg/L	3.9		11.3	
Total Phosphorus	mg/L	0.13		0.12	
Ortho Phosphorus	mg/L	0.02		0.09	
Conductivity	umho/cm	400		350	
Alkalinity	mg/L	128		156	
Chlorophyll	mg/m3	1.1		9.9	

Physical/Chemical Parameters

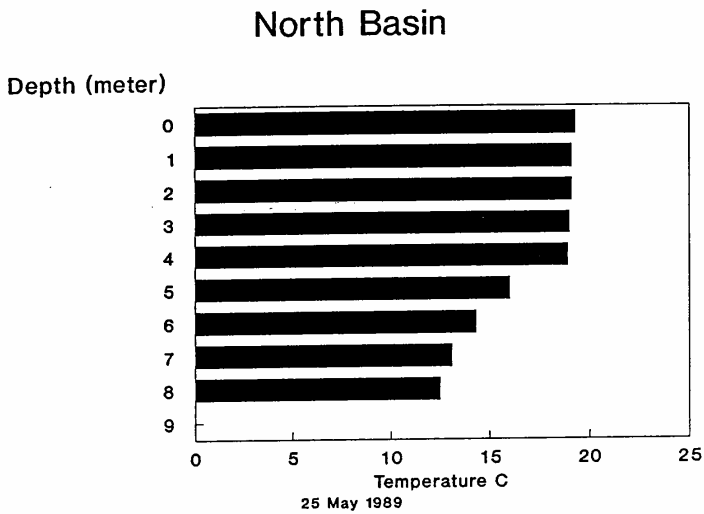
Temperature. Water column profiles clearly demonstrated that both the north and south basins were thermally stratified during May 1989 (Figure 6) with the thermocline in both basins being between three and four meters depth. The July pattern was quite similar in both basins (Figure 7).

Dissolved Oxygen. Midsummer oxygen values in the lower portion of the water column of lakes is governed by the degree of thermal stratification and the overall trophic state of the lake. The higher the trophic state (eutrophication) the greater the amount of organic matter falling to the bottom of the lake to decompose. If the lake is deep enough to stratify, oxygen is not replenished in the bottom layers readily and is consumed during the decomposition process. Thus, the higher the trophic state, the greater the likelihood that the lake becomes anoxic in the bottom of the water column (hypolimnion).

The lower portion of the water column (hypolimnion) of both the north and south basins displayed reduced oxygen levels during May 1989 (Figure 8), but total anoxia was not evident. As expected, the beginning of reduced oxygen corresponded to the bottom of the well mixed portion of the water column (epilimnion), the portion of the water column displaying the greatest temperature change per meter (thermocline). Thus, even early in the stratified period of summer, both basins were displaying symptoms of severe eutrophication.

Water column deoxygenation of both basins was even more pronounced during July (Figure 9). While the north and south basins maintained some oxygen throughout their respective water columns during May, both basins were devoid of oxygen below 3 meters by July.

When expressed as a mean for the entire water column, dissolved oxygen during both May and July was lower in the north basin, with the greatest interbasin difference noted during the latter month (Figure 10). Mean oxygen in both basins decreased from May to July reflecting progressive deoxygenation of the hypolimnion due to decomposition of phytoplankton settling out of the water column. The pronounced interbasin difference in mean oxygen noted for July is attributable to greater dominance of productivity in the south basin by aquatic weeds and suggests that daytime oxygen evolution via photosynthesis from phytoplankton and the extensive macrophyte zone in the upper portion of the water column is sufficient to offset the extreme deoxygenation found in profundal waters when calculating water column means. Water column oxygen values undoubtedly decline sharply even in surface waters at nite when plants



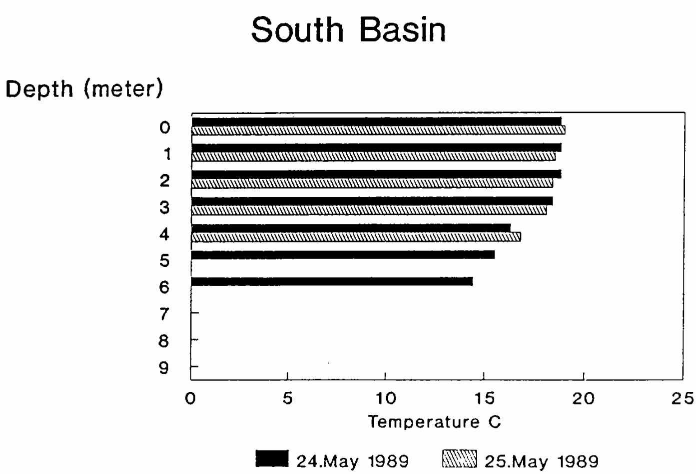
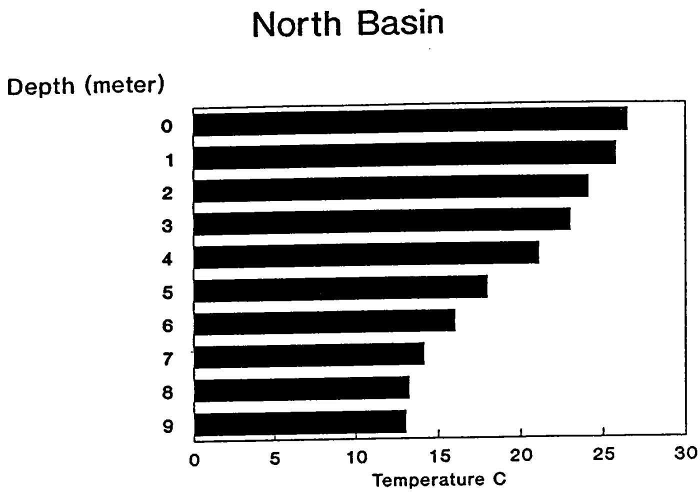


Figure 6. Water Column Temperature Profiles for the North and South Basins of Lake Bruce During May 1989.



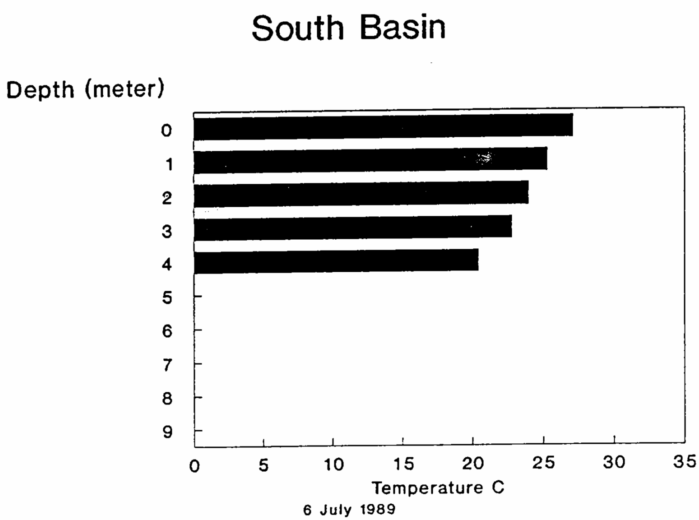
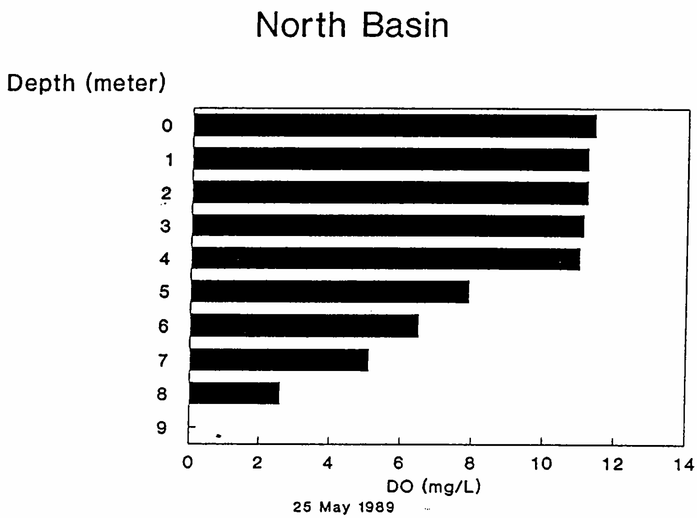


Figure 7. Water Column Temperature Profiles for the North and South Basins of Lake Bruce During July 1989.



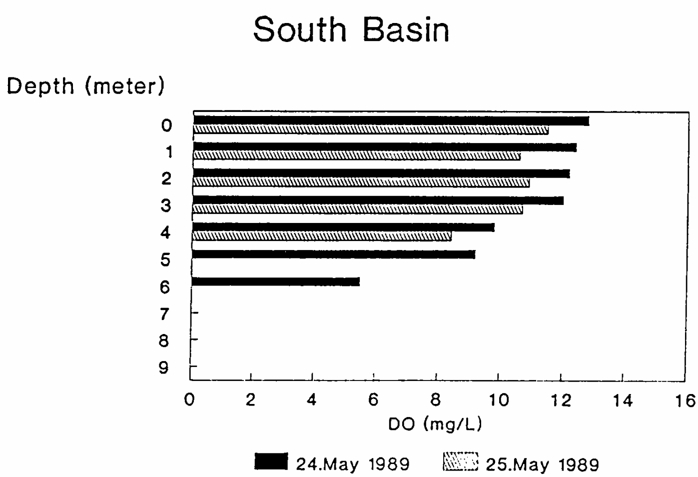
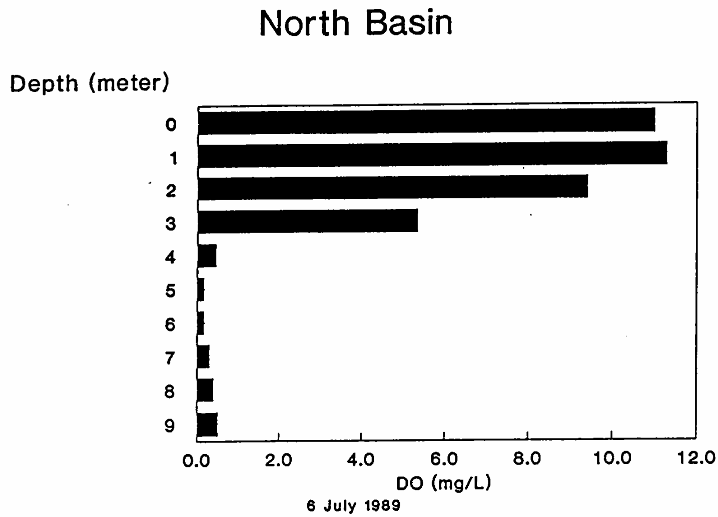


Figure 8. Dissolved Oxygen Profiles for the North and South Basins of Lake Bruce During May 1989.



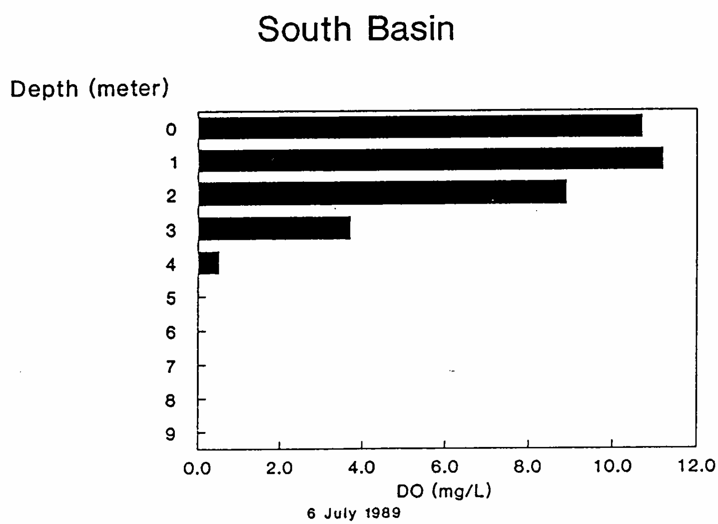
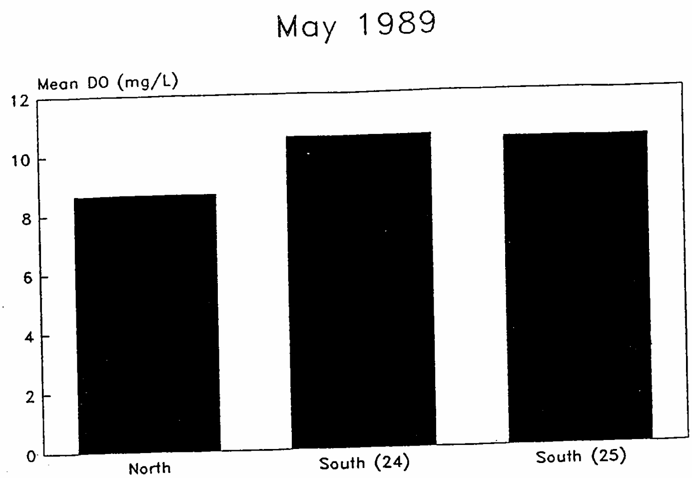


Figure 9. Dissolved Oxygen Profiles for the North and South Basins of Lake Bruce During July 1989.



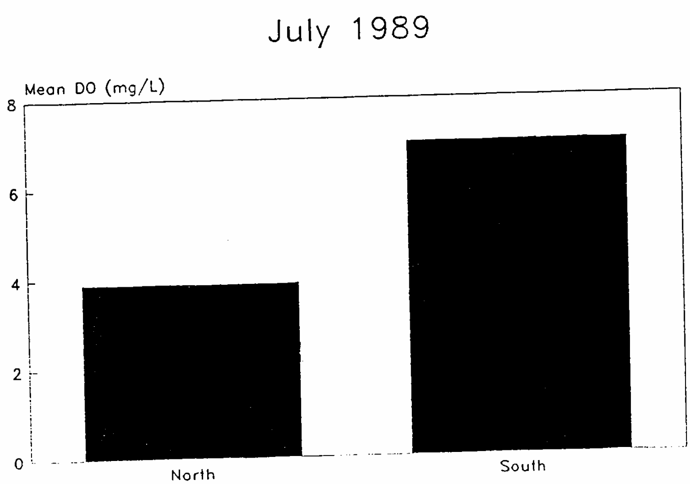


Figure 10. Mean Oxygen Values for the Water Column of the North and South Basins of Lake Bruce During May and July 1989.

are no longer photosynthetic.

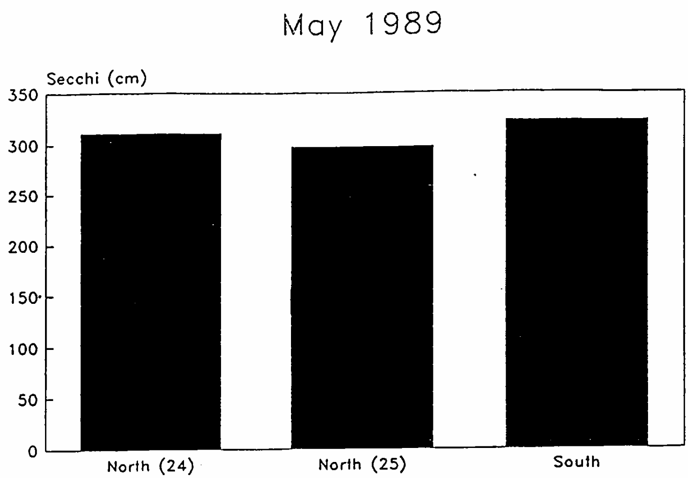
Historically, Lake Bruce has displayed severe deoxygenation of the water column below 9 feet (3 meters) depth during mid summer (Table 3) and mean oxygen values for the water column at 2.57-6.02 mg/L (Table 2). Assuming that previous surveys sampled the north basin, then the data recorded for 1989 were considered comparable to readings of the past 22 years (Table 9). Thus, it appears that while serious midsummer oxygen depletion is to be expected in Lake Bruce, the severity of this condition has changed little since at least 1967.

Secchi Disc and Photometer Transparency. As stated earlier in this report, the depth that a Secchi disc can no longer be seen in a water column is indicative of the amount of algae suspended in the water column to block light transmission. Thus, the shallower the Secchi depth during midsummer, the more productive (eutrophic) a lake is presumed to be. The Secchi depth was similar in the north (9.75 feet or 300 cm) and south (10.58 feet or 325 cm) basins of Lake Bruce during May 1989 (Figure 11). By July, Secchi transparency had decreased in both basins with the north (5.92 feet) being slightly clearer than the south (5.71 feet). Such a decline in Secchi values in midsummer is expected in highly eutrophic lakes as phytoplankton abundance increases in response to increasing temperature and reaches levels that have a marked effect on light transmission in the water column. The July 1989 values are considerably better than the 1.4-3.5 recorded during summer in previous surveys (Table 2). On the basis of Secchi data alone, the trophic state of Lake Bruce appears to have changed little since at least 1967.

A Licor photometer was used on both sampling dates to estimate the depth of the photic layer in the north basin of Lake Bruce. During May and July of 1989, the 1% compensation point for light was calculated as 21 feet and 15 feet, respectively. As also reflected in Secchi differences, the compensation point on both dates of 1989 was deeper than the 8 feet reported during August 1975.

Ammonia. Ammonia was below detection limits in Lake Bruce during May 1989, and was 0.08 mg/L during July (Table 9). The only previous measurement of this parameter was in 1975 when a value of 2.2 mg/L was recorded (Table 2).

Nitrite-Nitrate. This parameter during May 1989 was approximately a third of the 11.3 mg/L recorded in July (Table 9, Figure 12). The only previous measurement of this parameter was in 1975 when a value of 2.1 mg/L was recorded (Table 2).



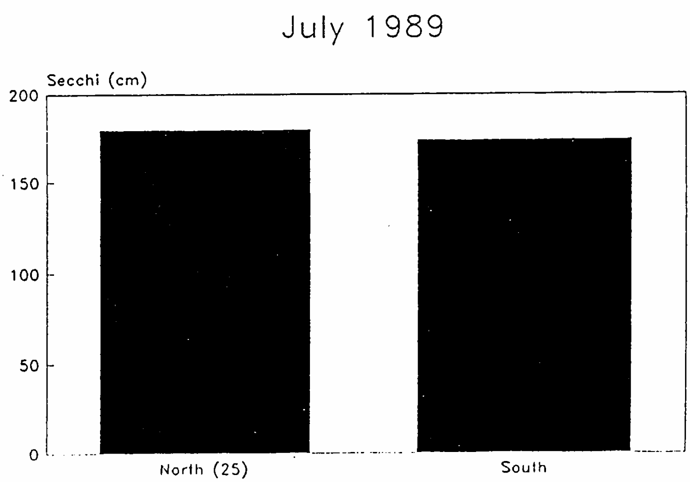


Figure 11. Secchi Disk Transparency for the North and South Basins of Lake Bruce During May and July 1989.

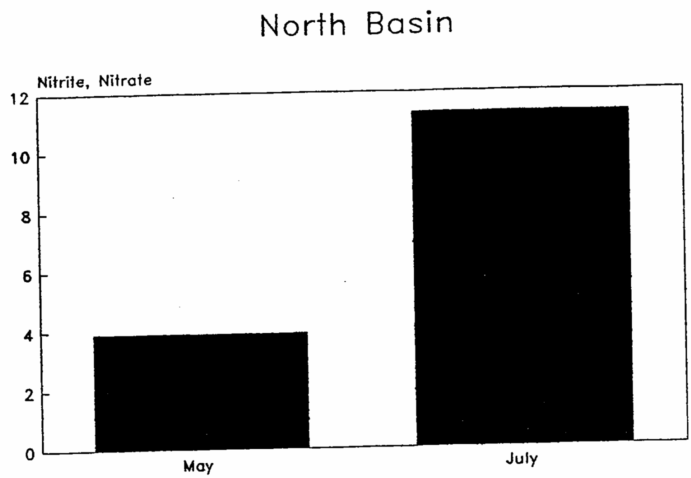


Figure 12. Nitrite-Nitrate Concentrations for Lake Bruce During May and July 1989.

Kjeldahl Nitrogen. The value for Kjeldahl nitrogen during May 1989 was approximately 40% greater than that recorded in July (Table 9, Figure 13). Both 1989 values (3, 4.5 mg/L) exceeded the only historical value (1.4 mg/L in 1988) for this parameter (Table 2).

Total Phosphorus. Total phosphorus concentrations were remained unchanged between May (0.13 mg/L) and July (0.12 mg/L) 1989 (Table 9, Figure 14). Values for 1989 were within the range (0.03-0.20 mg/L) reported for Lake Bruce during the past 19 years (Table 2, Figure 3). While it is tempting to suggest that total phosphorus concentrations have remained steady since at least 1970, it is important to note, however, that water column concentrations of phosphorus are somewhat misleading estimates of trophic state. It is entirely possible that total phosphorus loading to a lake could have increased markedly between years, while water column values remained constant or decreased. In lakes such as Bruce, which have experienced a pronounced increase in weeds, the phosphorus that is entering the system can be effectively trapped by the weed mass and actually decrease in the water column through effective competition with algae for this essential nutrient.

Ortho Phosphorus. Ortho phosphorus concentrations increased from May (0.02 mg/L) to July (0.09 mg/L) 1989 (Table 9). The 1989 values were similar to that reported in 1975 (0.09 mg/L), the only other time that ortho phosphorus has been measured (Table 2).

Conductivity. Conductivity dropped from 400 umhos/cm in May to 350 umhos/cm in July 1989 (Table 9, Figure 15). Both values are slightly higher than the 320 umhos/cm reported in August 1988 (Table 2). Given that the principal sources of conductivity in lakes such as Bruce are groundwater and runoff from the watershed, these data suggest that the watershed contribution to this parameter decreases throughout the duration of summer.

Alkalinity. Total alkalinity increased slightly between May and July 1989 (Table 9, Figure 16). The 1989 total alkalinity values (128, 156 mg/L) were lower than all previous readings except those of August 1977 and May 1978 (Table 2). Alkalinity is indicative of the amount of carbonate rich material dissolved in the lake water. As most of this carbonate enters the lake via watershed runoff, the data are suggestive that watershed runoff during 1989 may have been lower than many of the immediately preceeding years.

Chlorophyll. Chlorophyll is a good estimator of algal biomass in a lake. Chlorophyll values in Lake Bruce increased sharply between May (1.1 mg/m^3) and July (9.9 mg/m^3) 1989 (Table 9, Figure 17). Historical data for

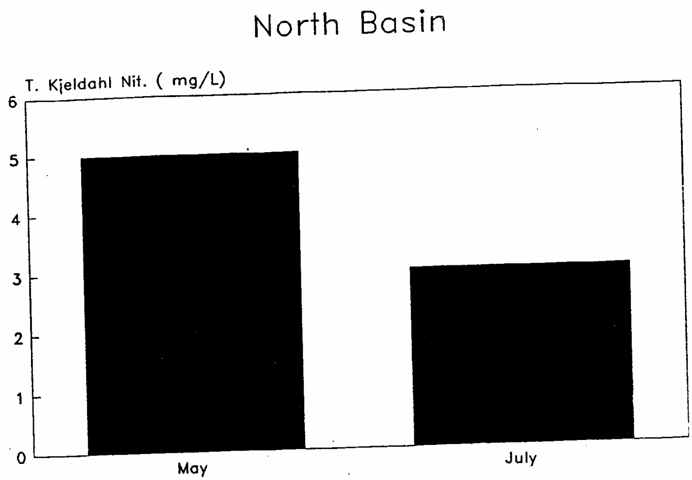


Figure 13. Kjeldahl Nitrogen Concentrations for Lake Bruce During May and July 1989.

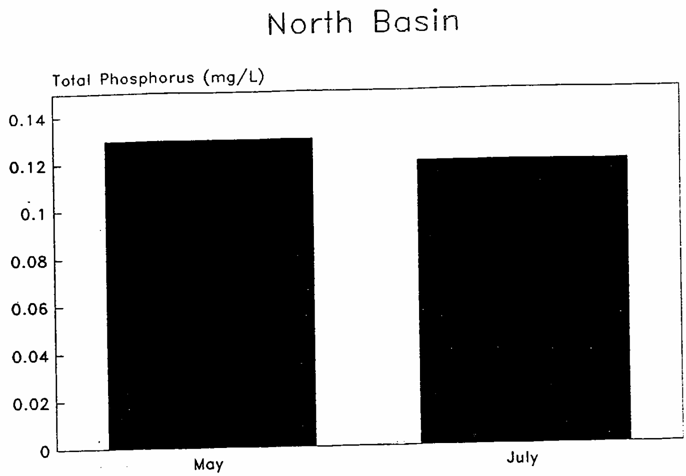


Figure 14. Total Phosphorus Concentrations for Lake Bruce During May and July 1989.

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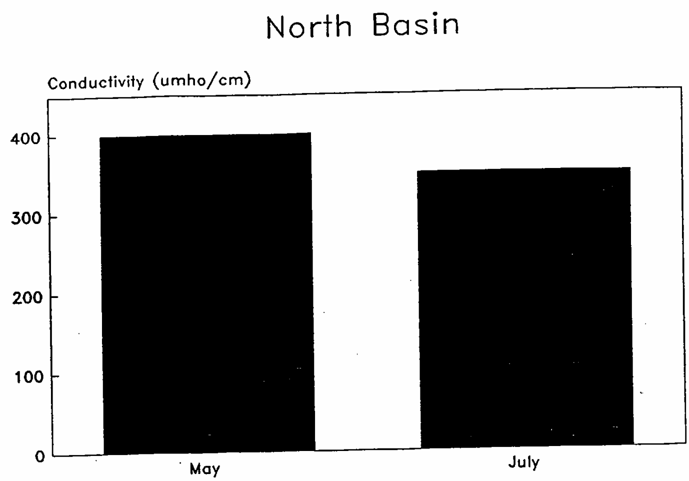

Figure 15. Conductivity Values for Lake Bruce During May and July 1989.

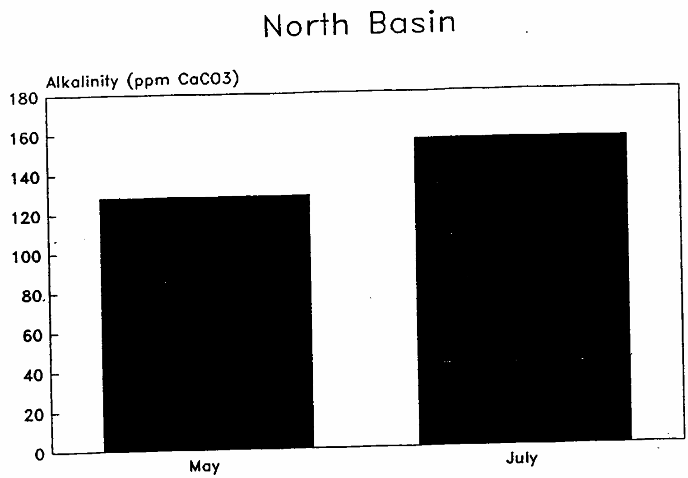

Figure 16. Alkalinity Values for Lake Bruce During May and July 1989.

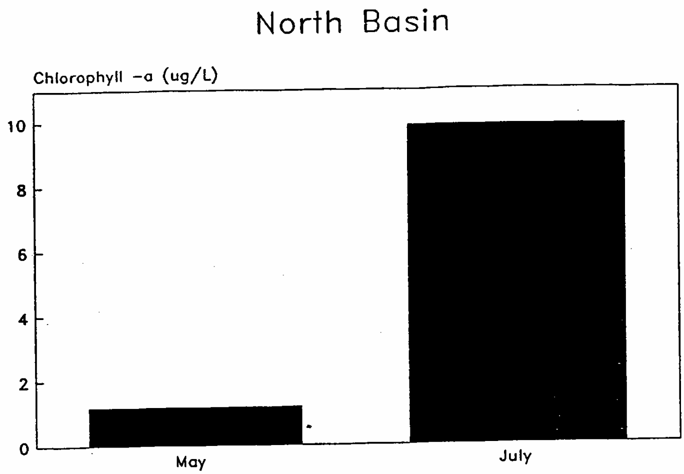

Figure 17. Chlorophyll Concentrations Lake Bruce During May and July 1989.

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chlorophyll were unavailable for comparison with the 1989 database. In general, however, values from Lake Bruce in 1989 generally were within the range exhibited by mesotrophic and eutrophic lakes.

ISBH Trophic State Index

Mr Harold BonHomme of the Indiana State Board of Health devised a eutrophication index specific to Indiana lakes based on summertime sampling of 307 lakes in the mid 1970's. Parameters included in the index construction were phosphorus, nitrogen forms, dissolved oxygen, light penetration and transmission, and phytoplankton abundance and group dominance. Ranges for each parameter were assigned eutrophy points, and the final eutrophication index value for a given lake represented the sum of eutrophy points from all parameters combined. The Indiana Department of Environmental Management (1986) updated the database and published the most recent form of the index.

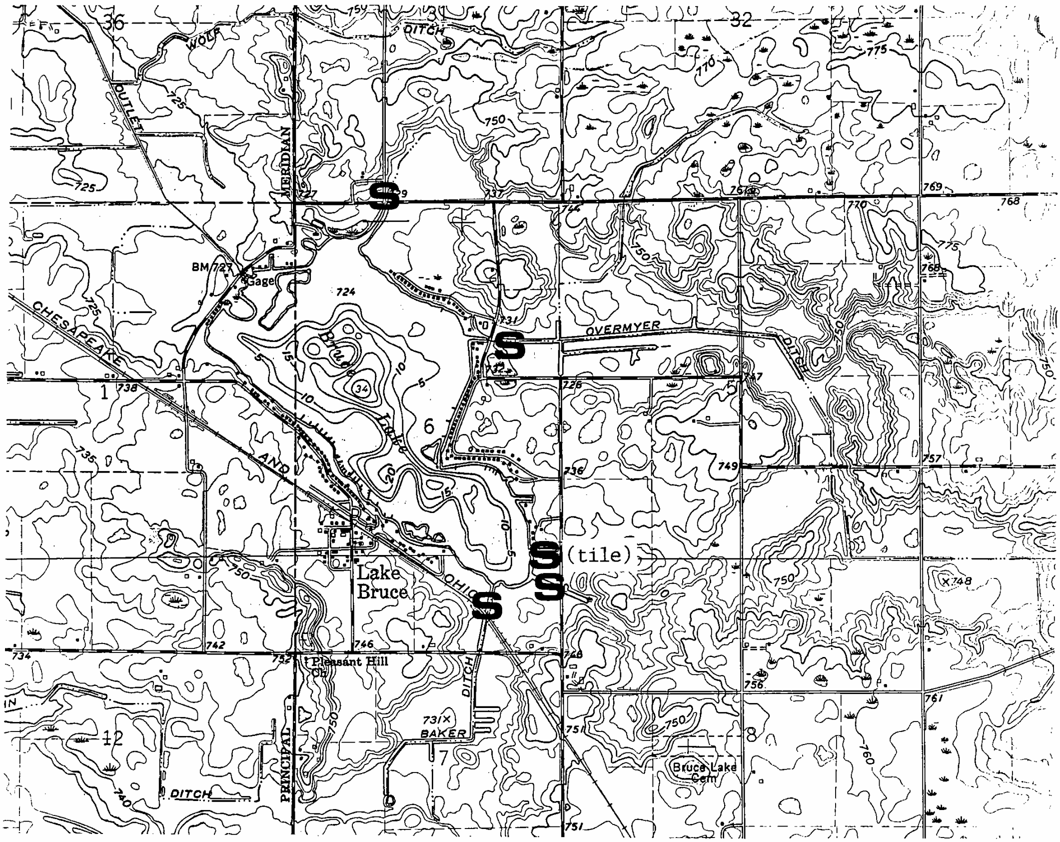
The 1975 eutrophication index for Lake Bruce was calculated by the Indiana State Board of Health as 61, thus assigning the lake to the category of poorest water quality, class III. In the current survey, we have calculated the IDEM eutrophication index from parameter means for the two sampling dates of 1989. Calculation of the index was as follows:

Parameter and Range		1989 Value	Eutrophy Pts.
I	Total Phosphorus 0.06-0.19 ppm	0.125	3
II	Soluble Phosphorus 0.06-0.19 ppm	0.055	3
III	Organic Nitrogen 2.0 ppm or more	~~3.75~~ 3.67	4
IV	Nitrate 2.0 ppm or more	7.6	4
V	Ammonia At least 0.5 ppm	0.08	0
VI	Dissolved Oxygen % Saturation @ 5 feet 120-129%	126	2
VII	Dissolved Oxygen % water col. with at least 0.1 ppm 66-75%	72	1

VIII	Light Penetration Secchi Disc Five feet or under	7.83	0
IX	Light Transmission Photocell: % light @ 3 feet 31-50%	49	3
X	Total Plankton per mL		
	Vertical tow from 5 feet 1,000-2,000/mL Blue-green dominance	 1800 Yes	 2 5
	Five foot tow including beginning of thermocline 1,000-2,000/mL Blue-green dominance Greater than 100,000/mL	 1800 Yes No	 1 5 0
	1989 Eutrophication Index		33

The eutrophication index for 1989 was calculated as 33. While the 1975 phytoplankton assemblage was dominated by the green alga Microspora and the diatom Synedra, the 1989 midsummer assemblage was dominated by the blue-green alga Anabaena and the diatom Melosira with Pediastrum, Anacystis, and Ceratium as the principal subdominants.

Water quality in Lake Bruce appears to have improved since 1975. It is likely that the 28 point decrease is a artifact given the fact that the eutrophication index is an estimate of the water column conditions in open water, and like all indices, does not include the extent and productivity of aquatic weeds. Historical evidence suggests that the extent of aquatic weeds in Lake Bruce has been expanding over at least the last decade. Expanding weed abundance is often associated with reduced nutrient and algal abundance in open water areas as the vegetated littoral zone successfully competes with open water phytoplankton for nutrients (Canfield et al. 1983). It is likely that water quality in Lake Bruce has not improved since 1975, but reflects the ability of aquatic weeds to effectively trap phosphorus before it can enter the open water areas of the lake.



STREAM MONITORING STATIONS, LAKE BRUCE

Figure 18 A

Stream Monitoring

> According to a Nonpoint Source Assessment Report, 1989, by the Indiana Department of Environmental Management, nonpoint source pollution, specifically sediments and nutrients from non-irrigated agricultural land is the primary threat to fisheries, wildlife production and the overall water quality of Lake Bruce...

Methods

At each station, two, 1-liter water samples were collected from the upper 15 cm of the water column. Water samples were analyzed for: calcium carbonate alkalinity, specific conductivity, pH, total nitrogen, total phosphorus and color. In addition to water quality measurements, stream flow was calculated using a General Oceanics mechanical flowmeter and a visual survey was conducted of stream and basin characteristics.

Stream Chemistry

Water chemistry data were collected on 23 March 1989 for five inlets to Lake Bruce: Frasa Ditch, Baker Ditch, Overmyer Ditch, Bruce Ditch, and Bruce tile at the southeast channel (Figure 18A). An additional sampling of Frasa Ditch was done on 4 April 1989.

Frasa Ditch drains the northern portion of the Lake Bruce watershed and enters a channel along the lakes northern shore. The area drained is flat to partially rolling terrain with drained areas being cultivated. Much of the land immediately surrounding the ditch is wooded and swampy. The sampling site for this stream was at the county road bridge north of the inlet to the lake.

The Baker Ditch drains the southern portion of the Lake Bruce watershed, a relatively open area under cultivation. A feed lot is also located in this portion of the watershed. This ditch enters Lake Bruce at the southern most point. Samples were collected approximately 5 feet north of the culvert under the abandoned railroad grade.

Overmyer Ditch drains the eastern portion of the watershed, the largest area drained by a single ditch complex. Much of the watershed is cultivated, the segment nearest the lake is open and uncultivated with the area immediately bordering the ditch being flat and swampy. Samples were collected slightly upstream from the county road bridge nearest the lake.

The Final two inlets enter the lake along the southeastern shore. The first we have designated Southeast Channel (Bruce tile). This channel cut is immediately north of Robert Miller's residence and receives field drainage via a culvert at its box end. This culvert presumably drains a rolling upland area that is cultivated. Samples were collected at the mouth of the culvert at the point of entry into the channel. The final inlet has been designated as Southeast Ditch (Bruce Ditch). This ditch drains the southeastern portion of the watershed immediately north of Bruce Lake Cemetery and enters the lake at its southeastern corner. Much of the upland is cultivated, and pastured, while the area adjacent to the ditch nearest the lake is a flat wooded swamp. Samples were collected at the railroad crossing closest to the inlet.

Stream flow at the time of sample collection was .250 CFS for Overmyer Ditch and 1.15 CFS for Fouts Ditch (Figure 18). Flow at the other inlets was normally less than that of the Overmyer Ditch.

With the exception of the Southeast Channel (pH 7.0), all inlet ditches had slightly acidic pH (Figure 19) with the lowest value (6.3) noted in Frasa Ditch. Total alkalinity (Figure 20) ranged from 160 to 230 mg/L with the highest value recorded at the Southeast Channel. Inlet stream values were much higher than the 128-156 mg/L reported in Lake Bruce during May and July 1989. Conductivity (Figure 21) displayed some variability between stream stations and ranged from 500 to 1,000 umho/cm. As with alkalinity, the highest value was recorded at the Southeast Channel.

Two forms of nutrients were measured at all inlet stations. Nitrate/nitrite nitrogen ranged from 8.17 mg/L in Southeast Channel to 11.23 mg/L in Frasa Ditch on 4 April after a 1.25 inch rain (Figure 22). Such values are considered very high. Total phosphorus (Figure 23) ranged from .07 mg/L (Frasa Ditch) to .13 mg/L (Southeast Channel). The rank ordering of the inlets for total phosphorus was roughly the opposite noted for nitrogen and appeared not to be strongly linked with stream flow characteristics. Total phosphorus values for the inlet sites were similar to the .02-.09 mg/L reported for Lake Bruce during 1989 as part of the present survey. Finally, total suspended solids (TSS) ranged from 1-18 ppm (Figure 24).

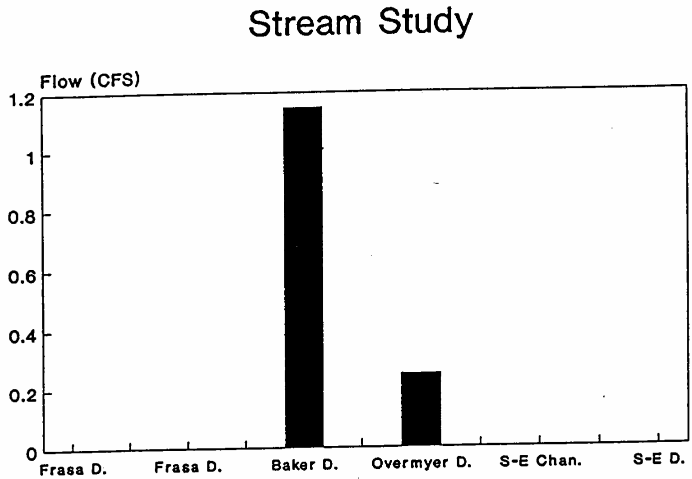


Figure 18. Flow in Ditches Draining the Lake Bruce Watershed For 23 March 1989. Note that the second Frasa Ditch Sampling is for 4 April 1989.

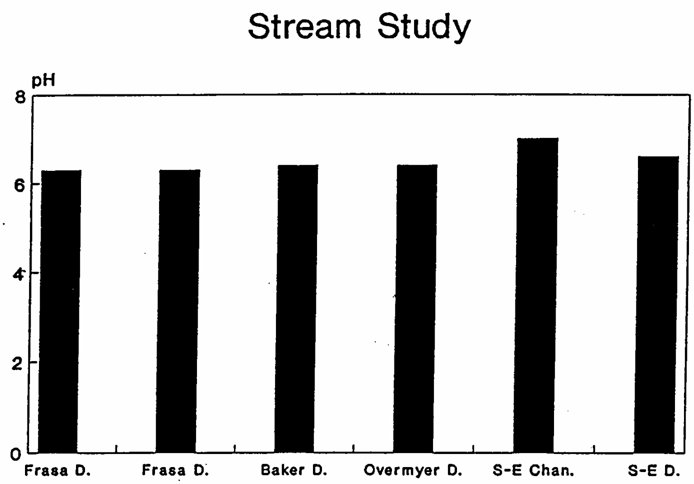


Figure 19. pH Values for Ditches Draining the Lake Bruce Watershed for 23 March 1989. Note that the second Frasa Ditch Sampling is for 4 April 1989.

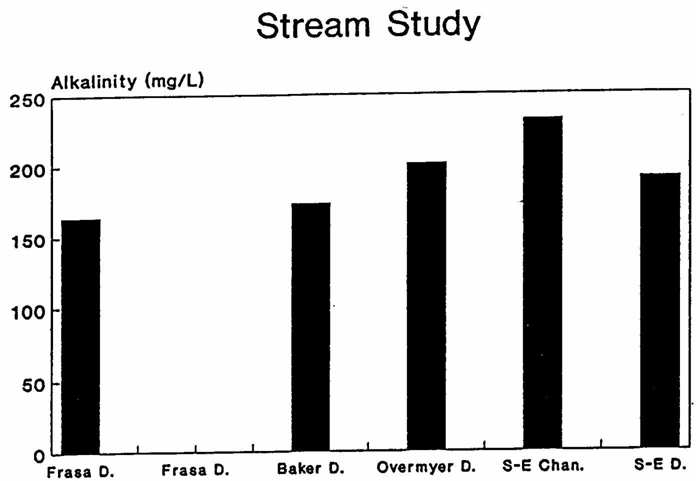


Figure 20. Alkalinity Values for Ditches Draining the Lake Bruce Watershed for 23 March 1989. Note that the second Frasa Ditch Sampling is for 4 April 1989.

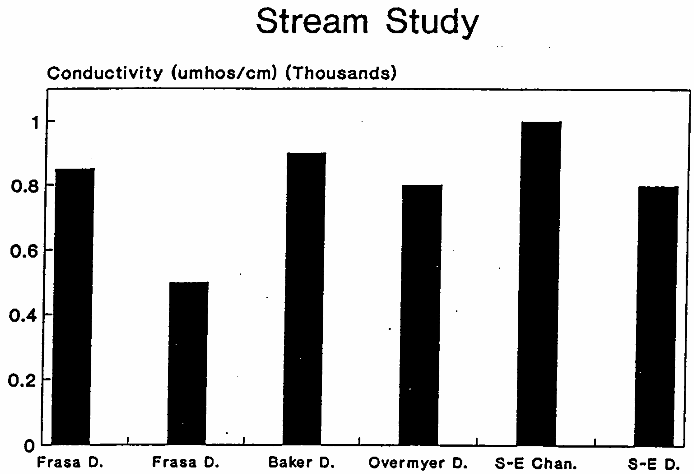


Figure 21. Conductivity Values for Ditches Draining the Lake Bruce Watershed for 23 March 1989. Note that the second Frasa Ditch Sampling is for 4 April 1989.

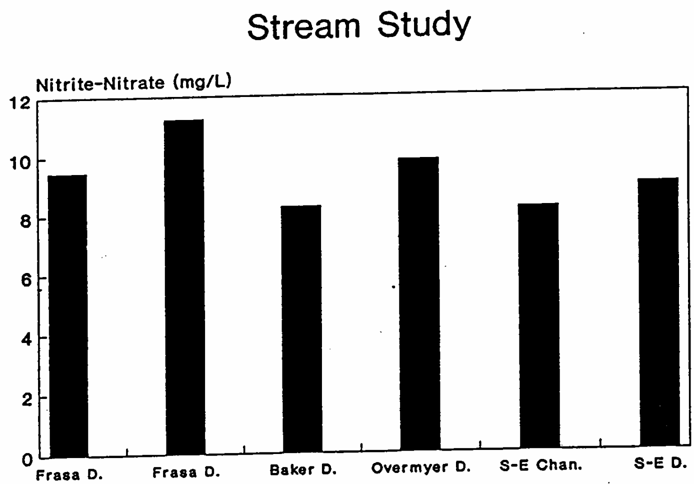


Figure 22. Nitrate-Nitrite Values for Ditches Draining the Lake Bruce Watershed for 23 March 1989. Note that the second Frasa Ditch Sampling is for 4 April 1989.

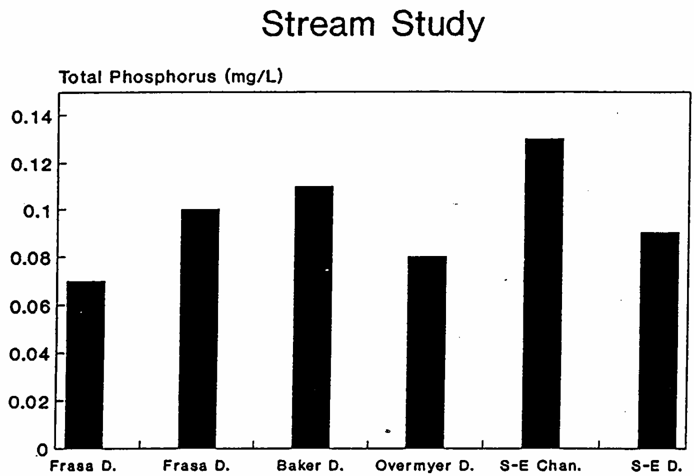


Figure 23. Total Phosphorus Values for Ditches Draining tne Lake Bruce Watershed for 23 March 1989. Note that the second Frasa Ditch Sampling is for 4 April 1989.

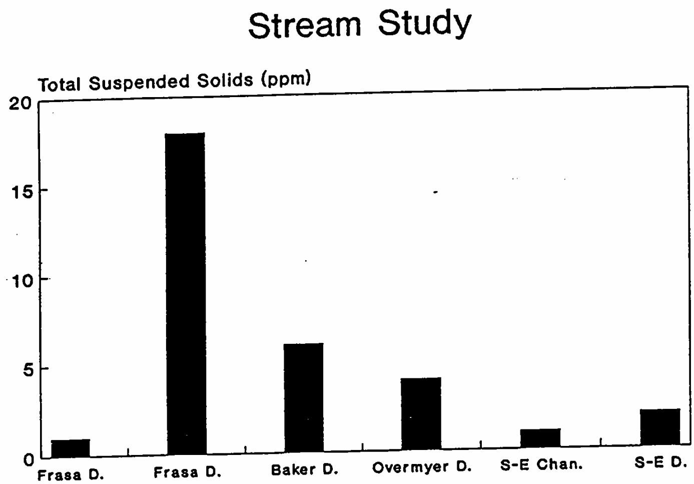


Figure 24. Total Suspended Solids Values for Ditches Draining the Lake Bruce Watershed for 23 March 1989. Note that the second Frasa Ditch Sampling is for 4 April 1989.

Microbiology

Water samples for fecal coliform analysis were collected from Lake Bruce in conjunction with the May and July 1989 water quality investigations. Samples were analyzed within eight hours of collection. The analyses followed the state approved membrane filter procedure and counts have been expressed as most probable numbers (mpn), a standard way of estimating bacterial numbers. The concentration of fecal coliform bacteria in the lake for 25 May was 2 mpn/100 mL of water. Bacteria numbers were essentially the same 6 July (less than 1 mpn/100 mL of water). Both bacteria counts at Lake Bruce during 1989 were well within state standards. It must be remembered that samples were collected in the middle of the lake and integrate the whole lake. Such data do not suggest that individual residences do not have problems with the functioning of their respective septic systems.

Macrophytes

A raytheon recording fathometer was used to estimate the biovolume of aquatic weeds in Lake Bruce . A total of 27 transects spanning the width of the lake were used as the data base. The plant survey was conducted in July 1989 and thus represents midsummer plant extents. Plant biovolume is defined as the percent of the water column at a given location in the lake that is filled with plant biomass. Thus, it is a measure of the extent of weed infestation throughout the lake system.

The distribution of plant biovolume in the Lake Bruce is presented in Figure 25. This figure demonstrates the extremely patchy distribution of plants in the lake. A much more informative way of looking at the data is to plot biovolume in increments of 20% water column infestation (Figure 26). The nearshore areas of the lake were considered 100% infested with weeds in 1989. The maximum extent of this area was considerably greater in the north than south basin. The eastern third of the north basin was so weeded that it was impossible to get a motor boat to the shore.

The extent of the 80% plant infestion zone was considerably smaller than the 100% category and in slightly deeper water. This zone reached its maximum aerial extent in the northwestern corner of the north basin. The 60%, 40% and 20% biovolume zones were in progressively deeper water in both basins and were aerially less extensive than both the less than 20% and weedless zones which were restricted to the deepest portions of both basins.

Aquatic plants filled 80-100% of the water column under 72% of the surface area of Lake Bruce (Figure 27). Using 80% biovolume as the cutoff defining serious management problems, 72% of the entire surface area this lake is plagued by excessive macrophytes. In marked contrast, only 10% of the surface area of Lake Bruce is characterized by plant biovolumes less than 20%, thus posing no management problems.

Macrophyte problems in Lake Bruce appear to be restricted to water less than 5 feet deep (Table 10). Approximately 84% of the area of the 0-5 foot depth interval is completely choked with weeds, while an additional 8% of the area has a biovolume of greater than 80%. The 5-10 foot depth interval is markedly smaller in aerial extent than the 0-5 foot interval, but still has 43% of its area with greater than 80% plant biovolume. The results clearly demonstrate that aquatic weeds display pronounced light limitation below five feet water depth and suggest that only those areas less than this critical depth are in need of plant management.

Actual plant heights for Lake Bruce are presented in Figure 28. For clarity, the distribution of individual 2-foot plant height increments have been presented in Figure 29. Plant heights 6-8 feet tall were recorded only in extremely small areas mostly in the north basin and are considered to have little bearing on the overall distribution of plant growth in the lake. Similarly, the north basin also had the greatest extent of plant growth 4-6 feet tall with maximum development along the eastern shore in water 5-10 feet deep.

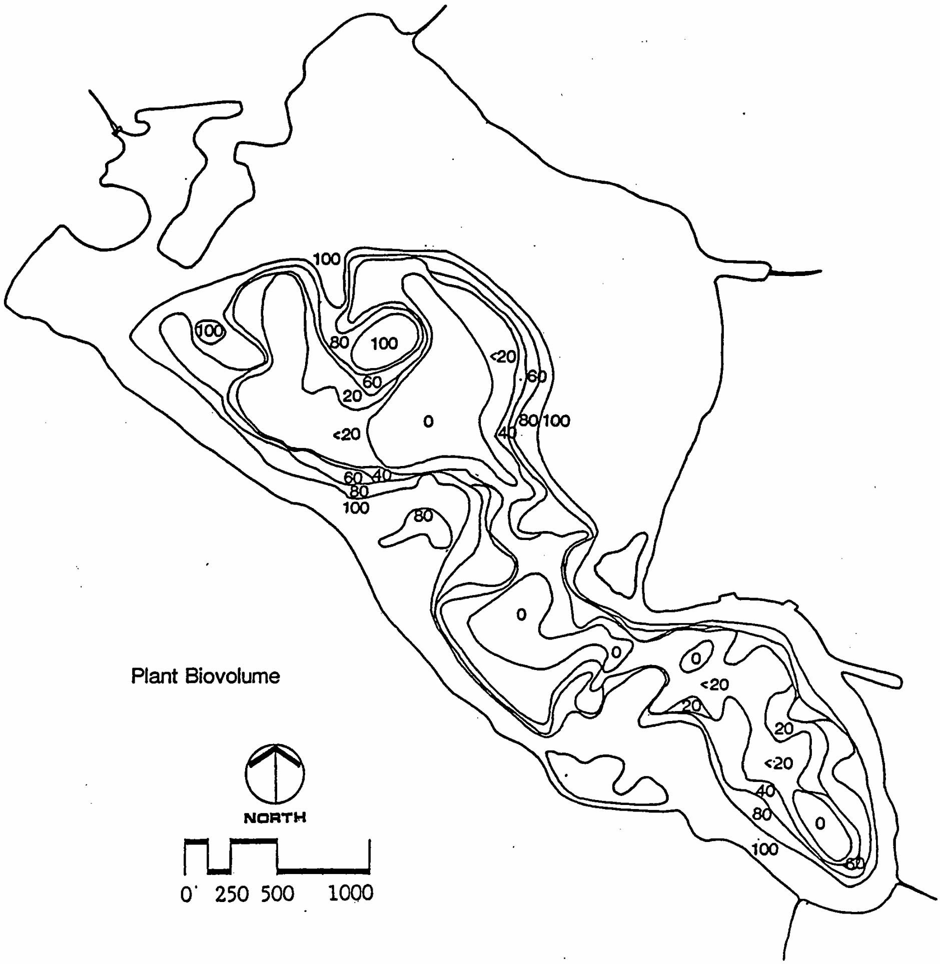


Figure 25. Distribution of Aquatic Weed Biovolume in Lake Bruce Lake for 1989.

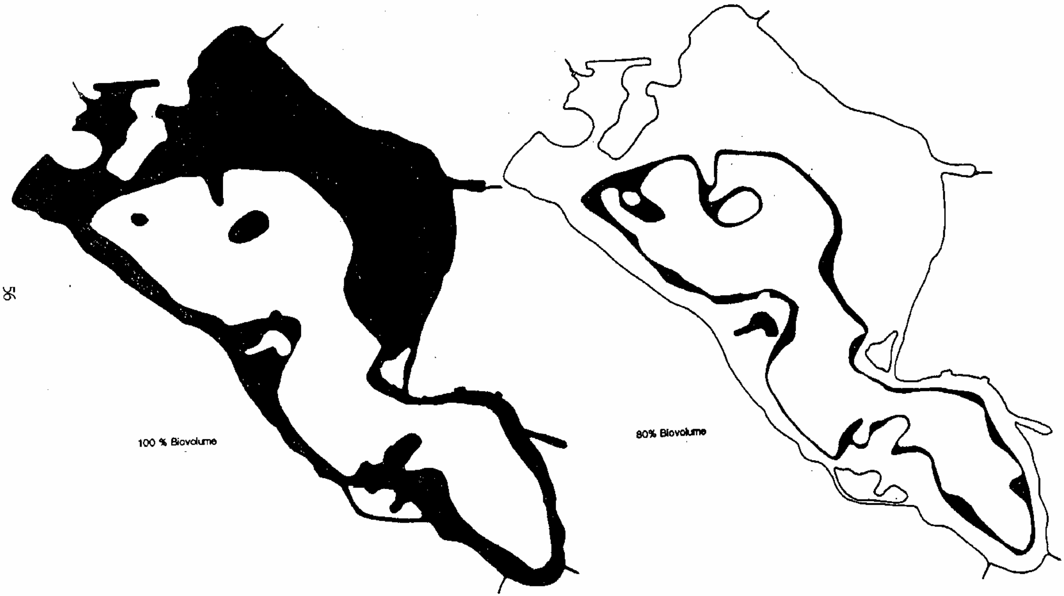


Figure 26. Plant Biovolume at Lake Bruce in Increments of 20% Water Column Infestation.

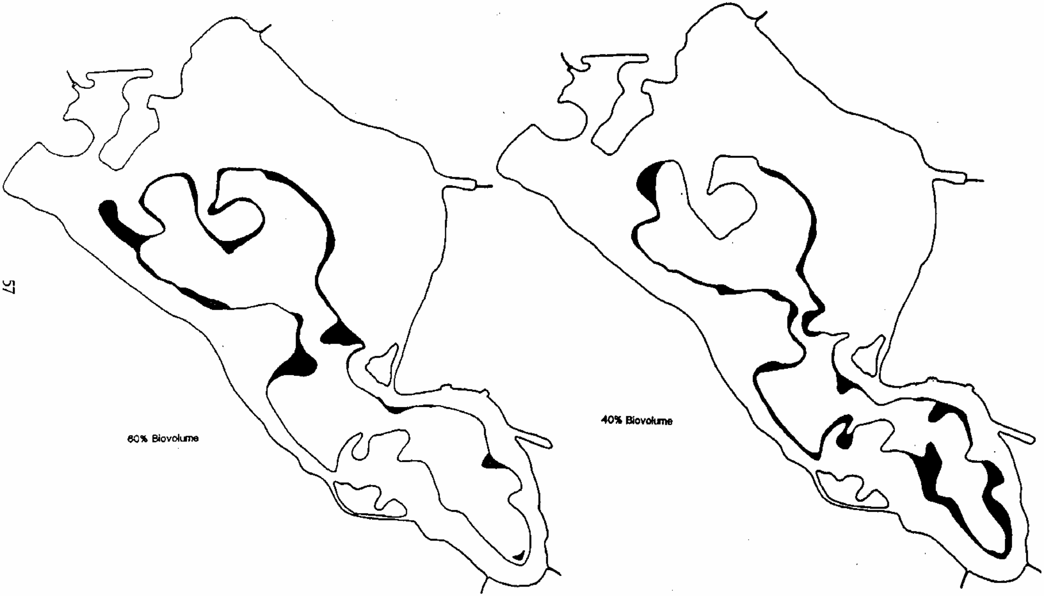


Figure 26. (Continued)

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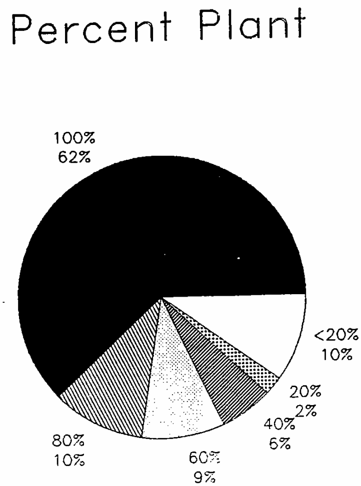


Figure 27. The Distribution of Plant Biovolume in Lake Bruce Expressed as a Percent of Water Column Infestation.

Table 10. Macrophyte Biovolume (20% Increments) Expressed as Percent Aerial Coverage for Both Individual Five Foot Contour Intervals and the Entire Area of Lake Bruce.

Interval	Biovolume %	Area Acres	% Area Contour Interval	% Lake Area
0-5 feet	100	125.9	84.8	53.3
	80-99	12.5	8.4	5.3
	60-80	3.7	2.5	1.5
	40-60	2.5	1.7	1.0
	20-40	0.9	0.6	0.4
	1-20	2.2	1.5	0.9
	0	0.7	0.4	0.3
5-10 feet	100	8.7	21.4	3.7
	80-99	8.7	21.5	3.7
	60-80	7.5	18.4	3.2
	40-60	8.4	20.7	3.6
	20-40	1.5	3.7	0.6
	1-20	4.7	11.7	2.0
	0	1.1	2.6	0.4
10-15 feet	100	2.2	5.6	0.9
	80-99	1.7	4.3	0.7
	60-80	9.4	24.0	4.0
	40-60	2.2	5.6	0.9
	20-40	2.1	5.3	0.9
	1-20	14.8	37.9	6.3
	0	6.8	17.4	2.9
15-20 feet	100			
	80-99			
	60-80			
	40-60			
	20-40	0.1	2.1	0.1
	1-20	0.5	8.8	0.2
	0	4.9	89.1	2.1
20-25 feet	100			
	80-99			
	60-80			
	40-60			
	20-40			
	1-20			
	0	1.8	100.0	0.8
>25 feet	100			
	80-99			
	60-80			
	40-60			
	20-40			
	1-20			
	0	0.92	100.0	0.4

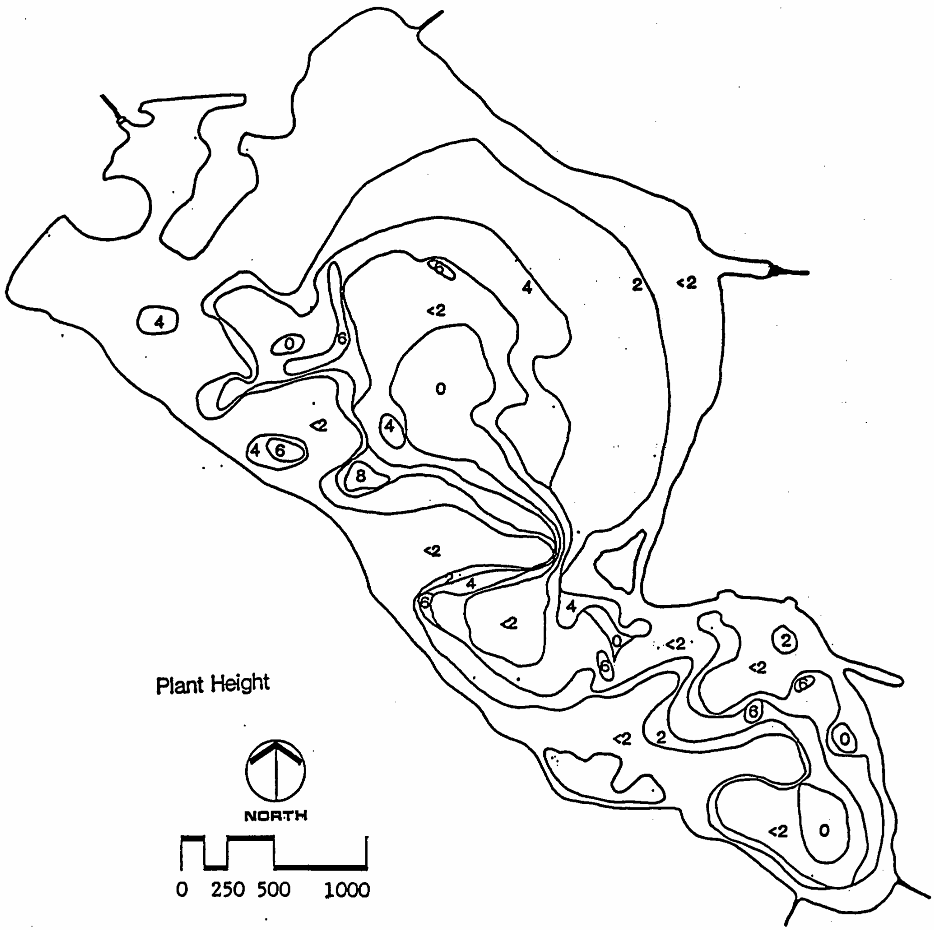


Figure 28. The Height of Aquatic Weeds in Lake Bruce in 1989.

Figure 29. The Distribution of Aquatic Plant Height in Lake Bruce by 2 Foot Height Increments.

Figure 29. (Continued)

Figure 29. (Continued)

Plant growth 2-4 feet tall reached maximum in the northern basin in water 5-10 feet. Plants less than 2 feet tall were found along the shore of both basins as well as in water greater than 10 feet deep. A majority of the weed problems along the shores of both basins are associated with such short vegetation that completely fills the water column of nearshore areas. As noted earlier, the deepest sections of both basins are completely weedless due to pronounced light limitation for plant growth.

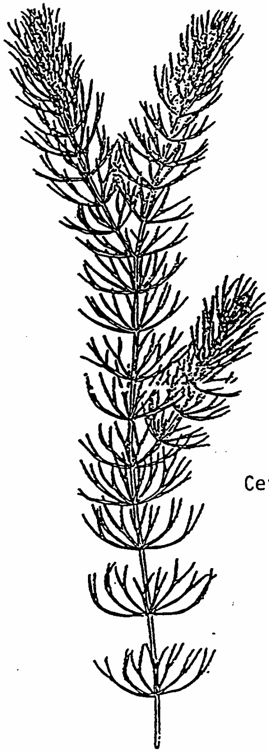
In addition to looking at the distribution of plant biomass in Lake Bruce, a qualitative survey was made to determine the distribution of the major plant species in the system. Sketches of the most important macrophyte species in Lake Bruce are presented in Figure 30, and their distributions are given in Figure 31. The exotic species, *Myriophyllum spicatum* (Eurasian watermilfoil), was the dominant submergent plant in Lake Bruce. This plant is the principal contributor to total plant biomass and should be the target of any aquatic management program. It is interesting to note that while the macroalga *Chara* was considered the major problem in the 1960's and early 1970's, effective control of this taxon has freed habitat for expansion of the more problematic Eurasian watermilfoil.

Nearshore areas of the south basin, especially near the mouths of inlets were characterized by patches of cattails (*Typha*) and water lilies (*Nuphar*). These plants are likely playing a beneficial role both for fish breeding habitat and the trapping of some of the nutrients and silt delivered by ditches. It is interesting to note that in general watermilfoil reaches its greatest extent in both basins in areas nearest the mouths of inlets. Such areas also were extensively colonized by floating and attached algae and duckweed (*Lemna*) suggesting the elevated availability of nutrients delivered from the watershed by ditches.

Fish

The Raytheon fathometer data recorded from the 27 cross lake transects were also used to provide a qualitative assessment of the fish community of Lake Bruce. Echos of fish in the water column appear on all fathometer recordings, and these were used to assess total fish abundance and the depth distribution of the population for each basin.

For interbasin comparison, fish data were presented on the basis of number individuals per 1000 feet of fathometer transect (Figure 32). The tracings suggest that fish in both basins were equally abundant (27/1000 feet transect North, 28/1000 feet transect South).



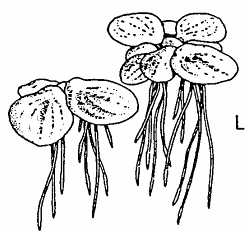


Figure 30. Common Plant Taxa Found in Bruce Lake during 1989. Drawings adapted from Fassett (1940) and Correll and Correll (1972).

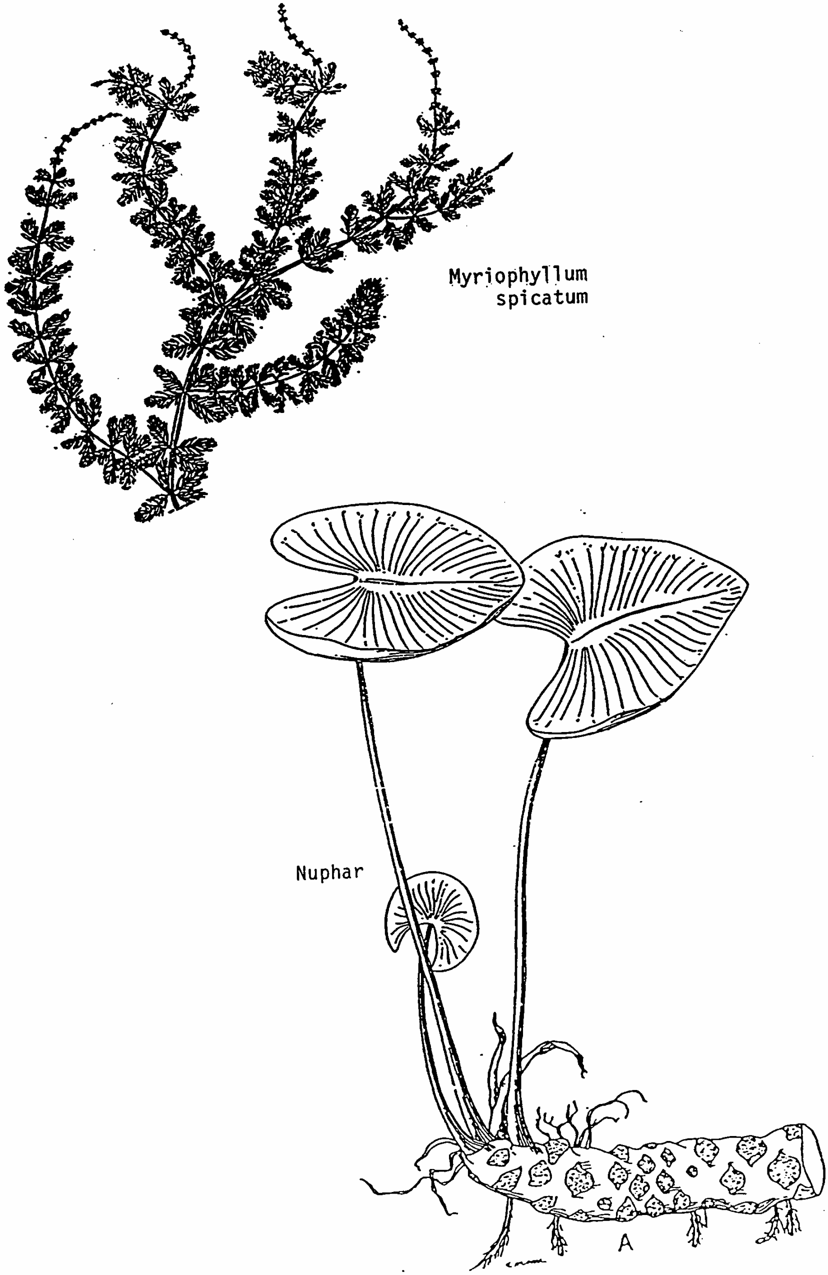
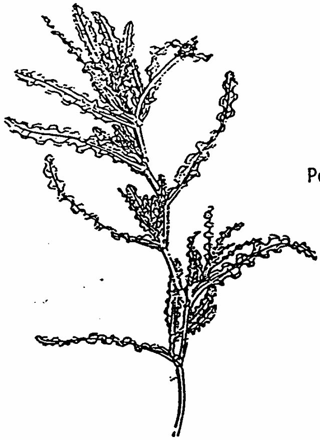
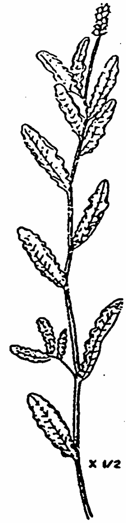
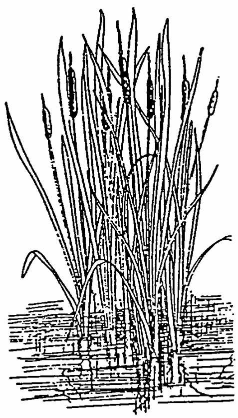


Figure 30. (Continued)



Potamogeton
crispus





Typha

Vallisneria

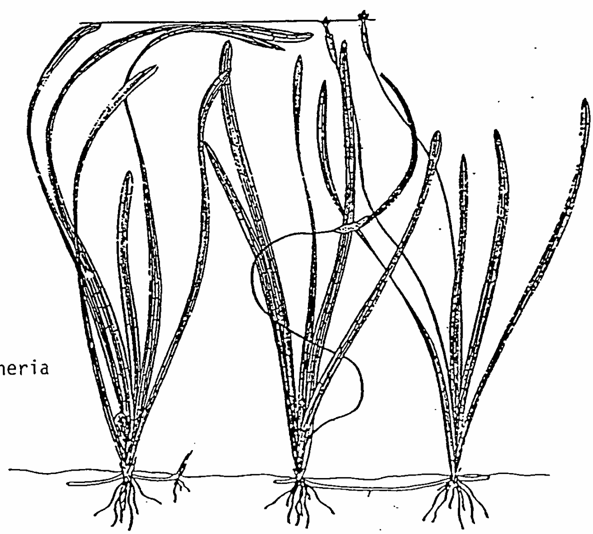


Figure 30. (Continued)

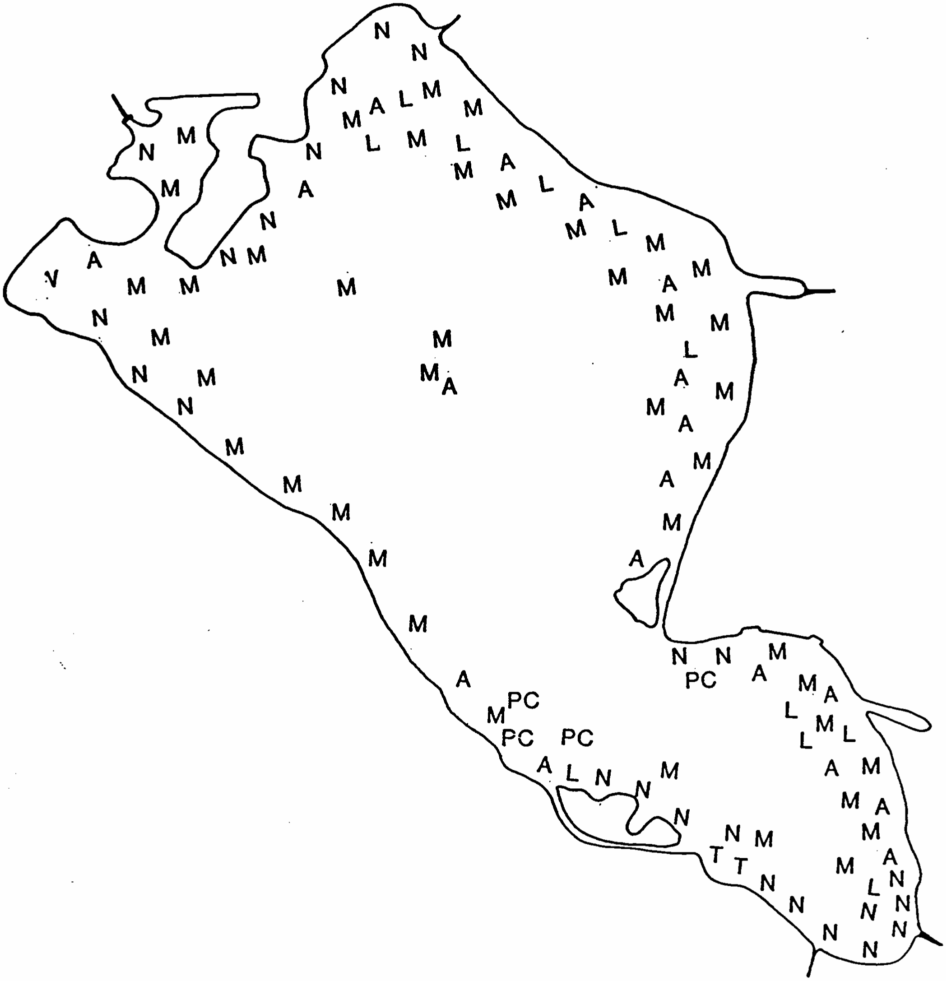


Figure 31. Distribution of Major Plant Taxa in Lake Bruce in 1989. Plants were: Algae (A), Ceratophyllum (C), Lemna (L), Myriophyllum (M), Nuphar (N), Potamogeton crispus (PC), Typha (T), and Vallisneria (V).

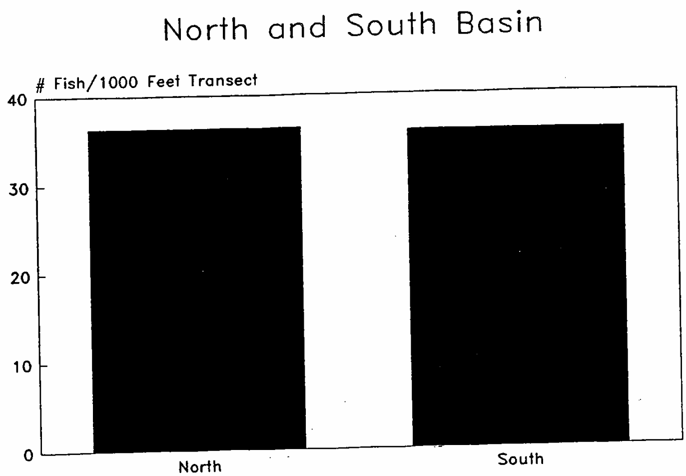


Figure 32. Semi-Quantitative Estimate of Fish in the North and South Basins of Lake Bruce in July 1989 Expressed as Number of Individuals Per 1000 Feet of Fathometer Transect.

Depth distributions of fish during July 1989 have been presented for the north and south basins (Figure 33) as well as the whole Lake Bruce system (Figure 34). The greatest density of fish in both the north (41% total abundance) and south (37% total abundance) basins was at a depth of 4-5 feet. Fish avoided shallower water, the area of highest water temperatures, as well as depths greater than 10 feet, the zone of reduced oxygen. It appears that fish during midsummer stay as deep as possible to avoid warm water while still having sufficient oxygen to avoid stress, but it must also be remembered that the extremely dense macrophyte growth in water less than 10 feet may also be limiting fish abundance. If trophic state can be reduced and macrophytes controlled, fish will expand their depth distribution as shallow water areas can be colonized and oxygen concentrations in the deeper portions of the water column increase.

Bathymetric Map and Lake Infilling

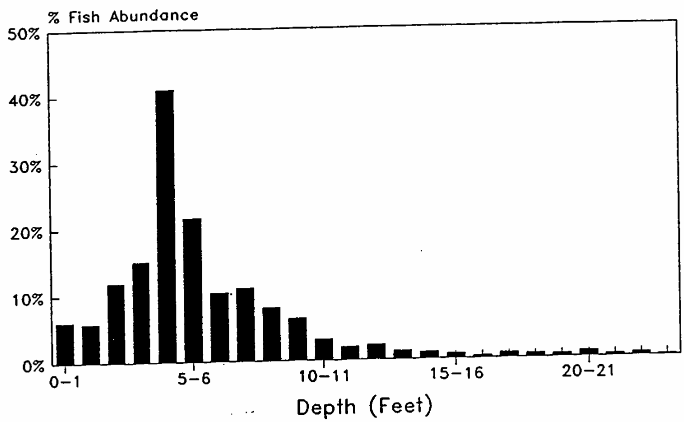
The Indiana DNR in association with the United States Geological Survey published a bathymetric map of Lake Bruce based on a survey of 1955 (Figure 35). Depth contours were constructed at five foot intervals for lake. The current study constructed an updated bathymetric map for 1989 based on fathometer recordings obtained from 27 lake transects (Figure 36). Following convention established by the 1955 map, five foot contours were constructed for the 1989 map.

It is obvious that the depth configuration has changed markedly in the past 34 years. A vast majority of Lake Bruce in 1955 was less than 5 feet deep with the 10-15 foot contour being of the second largest aerial extent (Figure 37). Maximum depth was in excess of 30 feet. The 0-5 foot contour still had the greatest aerial extent in 1989, but the 5-10 and 10-15 foot contours were of comparable area. Depths greater than 25 feet were extremely limited in area.

A comparison of the depth distributions of Lake Bruce for 1955 and 1989 is provided in Figure 38. In the past 34 years, the 0-5 and 5-10 foot contours increased in aerial extent approximately 14% and 44%, respectively. In marked contrast, all five-foot contours greater than 10 feet have decreased in area since 1955.

Infilling was not uniform throughout Lake Bruce but was most pronounced in the southern portion of the south basin and the northern portion of the north basin. It is clear that basin sedimentation is strongly controlled by ditch input of watershed erosion products. This has resulted in a major volume loss for all depth contours during the past 35 years. It appears that the volume of Lake Bruce has been

North Basin



South Basin

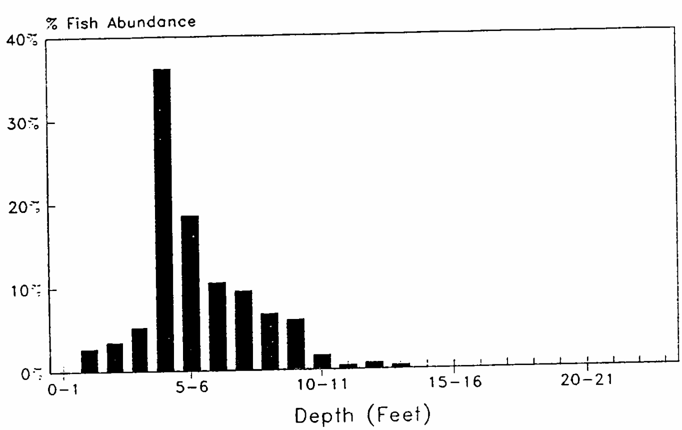


Figure 33. Depth Distribution of the Fish Community in the North and South Basins of Lake Bruce in July 1989 as Estimated from Fathometer Transects.

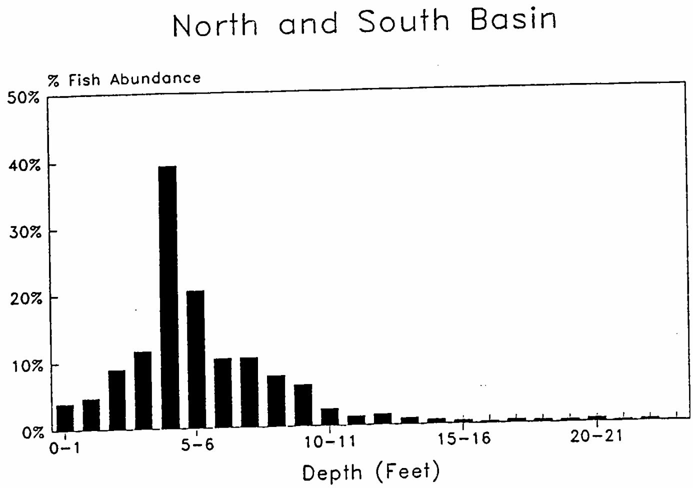


Figure 34. Depth Distribution of the Fish Community in Lake Bruce in July 1989 as Estimated from Fathometer Transects.

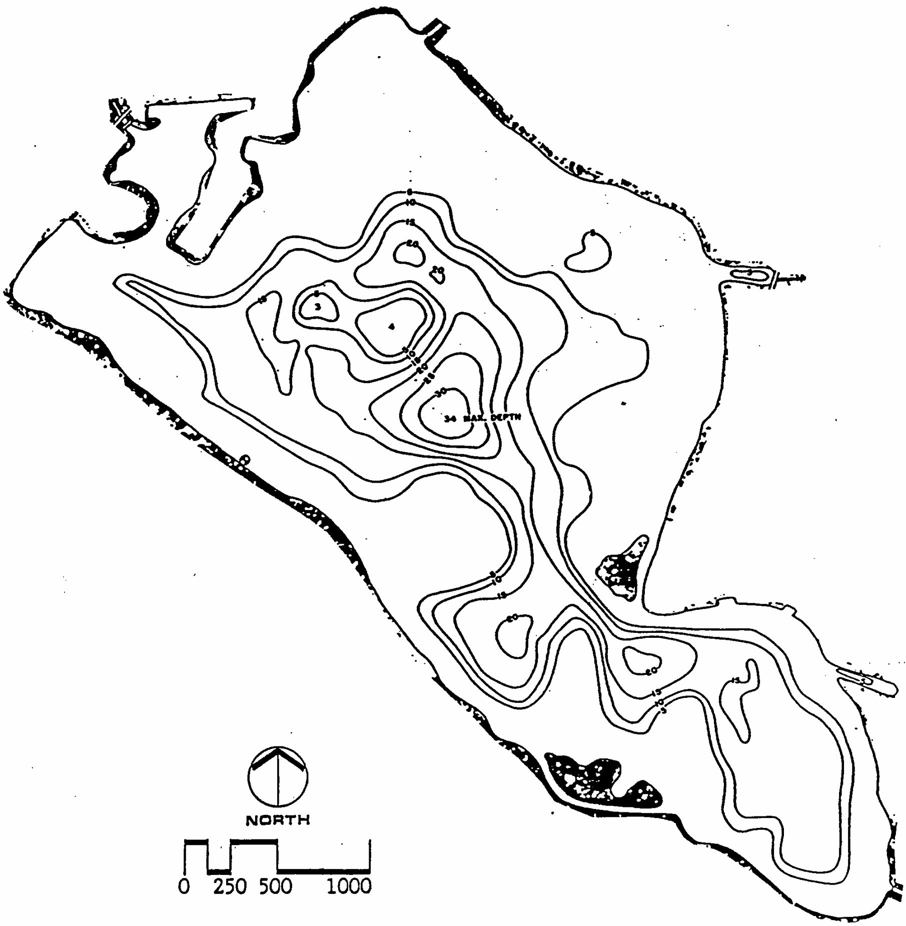


Figure 35. Bathymetric Map of Lake Bruce from 1955.

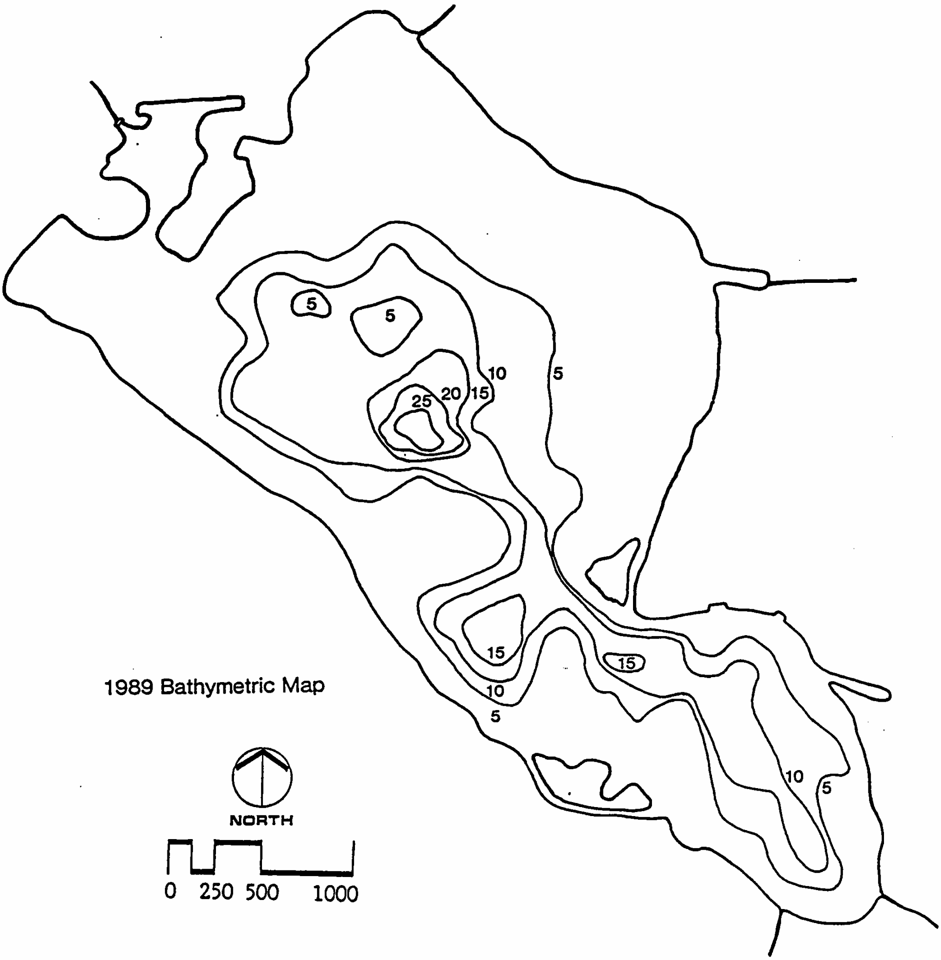
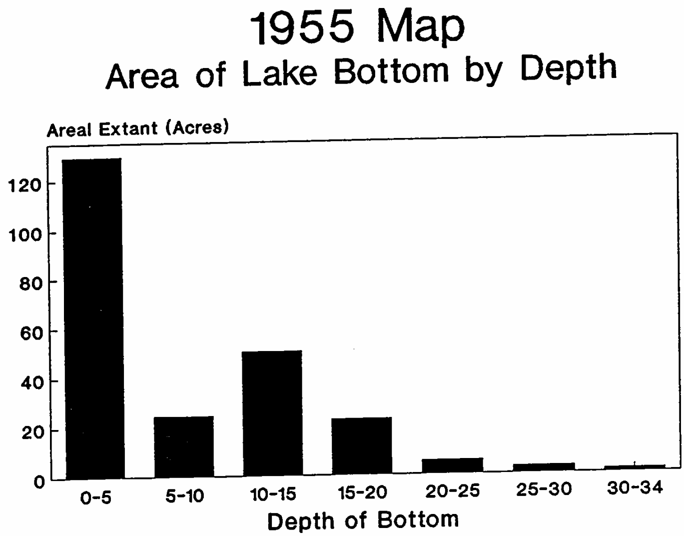


Figure 36. Bathymetric Map of Lake Bruce from 1989.



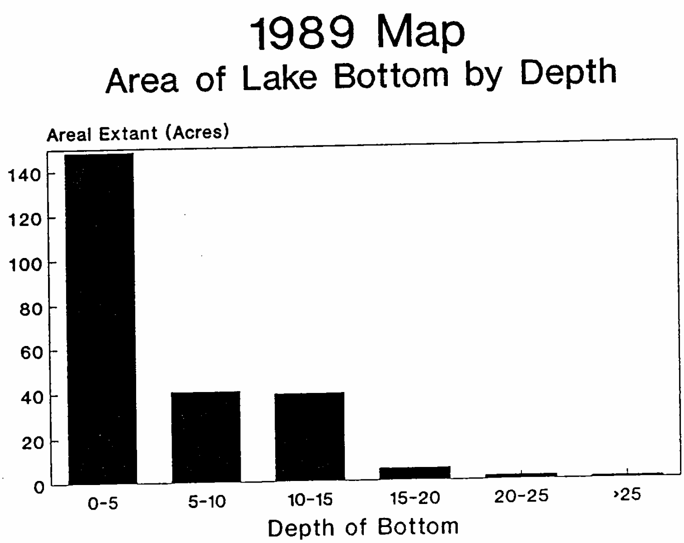


Figure 37. Aerial Extent of Individual Depth Contours of Lake Bruce for 1955 and 1989.

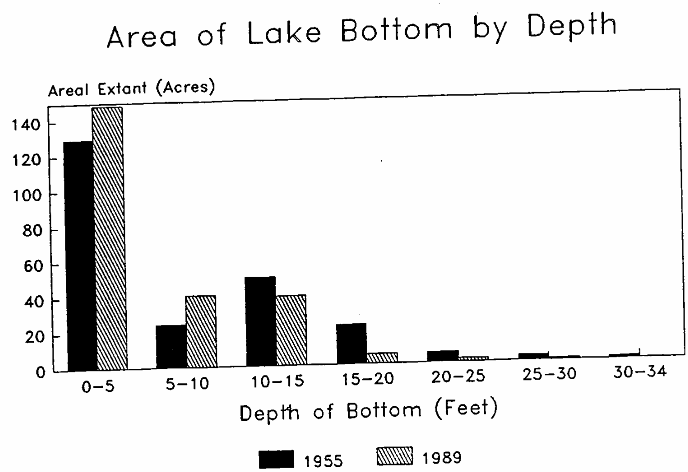


Figure 38. Comparison of the Aerial Extent of Individual Depth Contours of Lake Bruce for 1955 versus 1989.

reduced by approximately 25% since 1955 with sediment deposition averaging 0.69 inches per year throughout the lake. This deposition rate was estimated by dividing the total volume of sediment accumulated between 1955 and 1989 by the area of the lake and assumes equal deposition throughout the basin. As early as 1967 the DNR noted the build up of silt deposits at the mouths of all inlets. The same observations were made in both 1973 and 1975, and it was suggested that erosion from the watershed was the likely source for this material.

Shallow water shoaling is likely the result of within lake erosion and redeposition coupled with delivery of watershed erosion material. Two factors are likely responsible for shallow water sediment erosion and associated redeposition in deeper water. The grasses, cattails and other emergent vegetation growing in nearshore areas act to reduce the erosion action of waves. Our research at Lakes-of-the-Four-Seasons (Crisman and Eviston 1989) and Koontz Lake (Eviston and Crisman 1988) elsewhere has clearly demonstrated that removal of such vegetation by homeowners wanting easier access to their docks enhances the erosion action by waves and thereby promotes shoaling of offshore areas. The second factor for promoting shallow water erosion is waves generated by boats. Our research at Lake Maxinkuckee (Crisman et al. 1990) clearly addressed this point. Waves are normally only produced in lakes during storm events. Intense boating activity produces waves that approximate those generated during storms. Such waves increase nearshore erosion, stir nutrients from bottom waters and promote algal growth. While boating has likely contributed to basin shoaling, it is impossible to separate its importance from that of sediment eroded from the watershed as a contributing factor for the overall observed basin infilling at Lake Bruce.

Sediment Studies

Sediment Contaminants

A piston coring device equipped with a clear plexiglass tube was used to collect a one-meter core from the deepest section of Lake Bruce. This technique permitted examination of the core to insure that the sediment-water interface was not disturbed during the coring operation. The core was extruded in 10 cm sections and placed in labelled plastic bags. All core material was kept cool at 4^{o} C until analyzed. Prior to analysis, the 0-10 cm interval was thoroughly mixed and extracted for metal and organic contaminant analyses. This upper most interval provided sufficient material for our investigation.

The metals and organics data are presented in Table 11. A total of 19 metals were analyzed with the highest concentrations being exhibited by calcium, magnesium, iron, and manganese. All metal values were considered within the range expected for the glaciated portion of Indiana. In addition, 24 possible organic contaminants were analyzed. As with the metals, concentrations were not considered to pose any environmental threat. Given that none of the 43 analyzed parameters were considered to exceed permissible levels, it is most probable that the sediments throughout the remainder of Lake Bruce are free from serious chemical contamination as well.

Sediment Core Profiles

A sediment core was collected at the deepest location of Lake Bruce (Figure 39) by means of the same piston coring device described in the previous section of this report. As always, the plexiglass tubing permitted inspection of the core to insure that the sediment-water interface was left undisturbed during the coring operation. Only the core which we felt absolutely met this requirement was saved for analysis. The total core length collected from Lake Bruce was 124 cm.

The core was extruded within two hours of collection and sectioned at 1 cm intervals with each sample being placed in a plastic bag for storage. All samples were then kept at 4^{o} C until analyzed. In addition to wet weight for select core levels, organic content was calculated as the difference in weight between the wet weight and that after drying at 100^{o} C for 24 hrs. Inorganic content was calculated from the weight difference of the sample dried at 100^{o} C for 24 hrs and ashed at 500^{o} C for one hour. Phosphorus was determined by the standard ascorbic acid colorimetric method using filtrate collected from an HCl digestion of the sediment sample.

Water content of the Lake Bruce core remained unchanged at approximately 75% from 120 cm to 14 cm above which it increased progressively to 87% in the most recently deposited sediment (Figure 40). Such increased "soupiness" at the surface is considered typical of eutrophic lakes.

The profile of sediment inorganic content is presented in Figure 41. Sediment inorganic content remained relatively constant at approximately 80% throughout the length of the core. There was no evidence for an increase in the delivery of inorganic material in the recent past. The sediment organic content profile was the mirror image of the inorganic profile (Figure 42). Organic content oscillated between 17-23% throughout the length of the core profile.

Table 11. Concentrations of Metals and Organic Chemical Contaminants in Surface Sediments of Lake Bruce.

METALS	ug/g dry wgt	ORGANICS	ug/g dry wgt
% Solids	41.6	2,4,5-T	<0.7
Ag	<5	2,4,5-TP (Silvex)	<0.7
Al		2,4-D	<0.7
Ba	350	2,4-DB	<0.7
Be	<2	B-BHC	<0.01
B	1	D-BHC	<0.01
Cd	2	Methoxychlor	<0.2
Ca	388000	Toxaphene	<0.2
Cr	4	4,4'-DDD	<0.02
Cu	1	4,4'-DDE	<0.02
Fe	2690	4,4'-DDT	<0.02
Pb	3	A-BHC	<0.01
Mg	7460	Aldrin	<0.01
Mn	621	Chlordane	<0.02
Mo	10	Dieldrin	<0.01
Na	296	Endosulfan I	<0.02
Ni	3	Endosulfan II	<0.01
Sr	503	Endosulfan sulfate	<0.05
Ti		Endrin aldehyde	<0.02
V	18	Endrin	<0.01
Zn	4	G-BHC (Lindane)	<0.01
		Heptachlor epoxide	<0.05
		Heptachlor	<0.01
		PCB's	<0.05

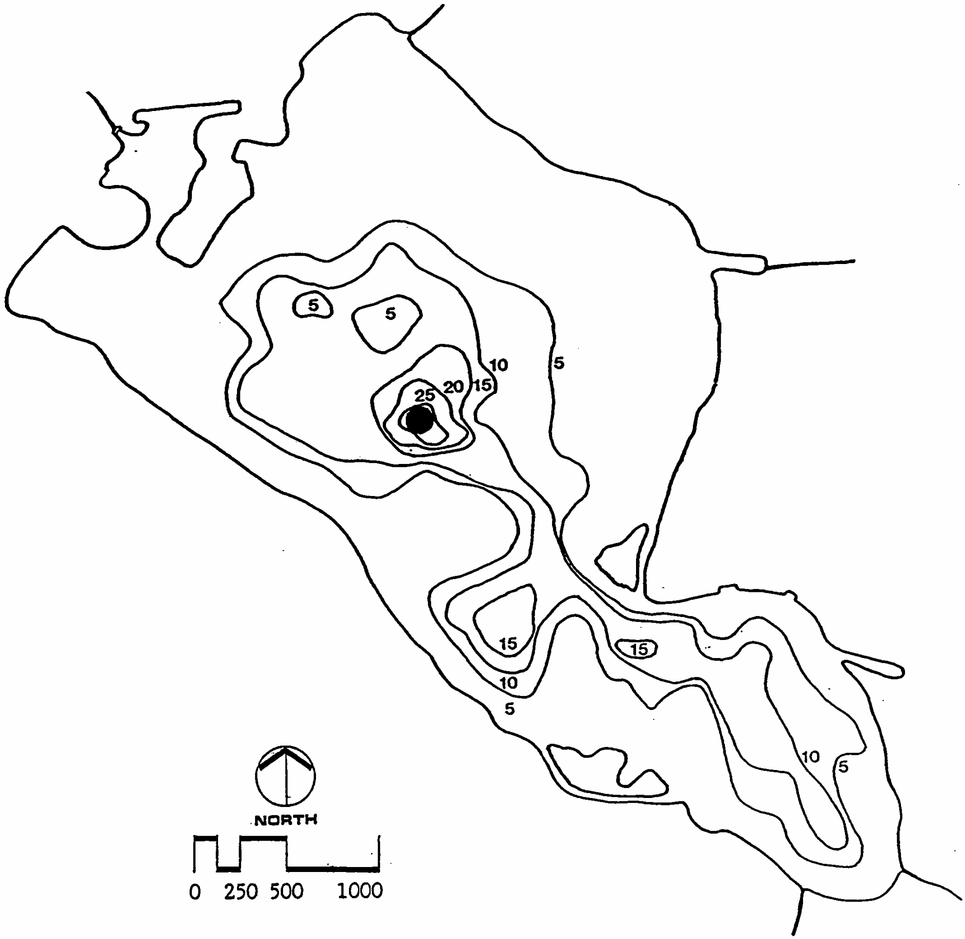


Figure 39. Site of Sediment Core Collection in Lake Bruce During 1989.

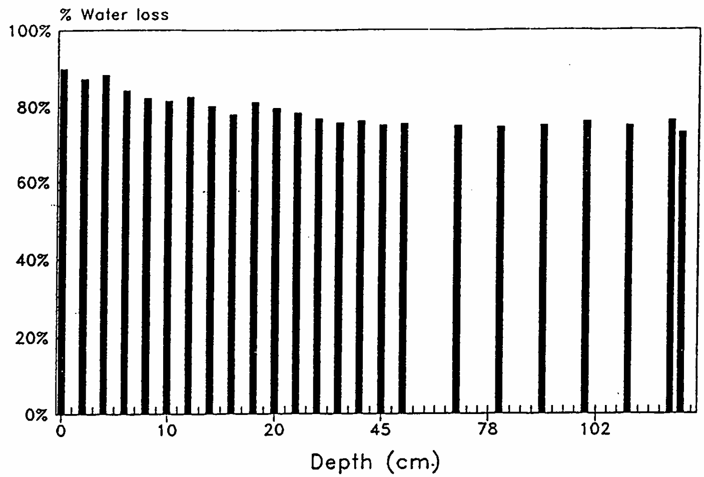


Figure 40. Profile of Percent Water in the Sediment Core From Lake Bruce.

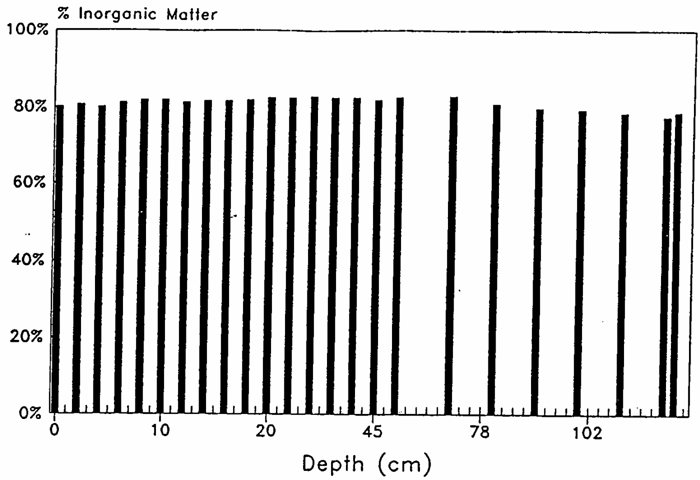


Figure 41. Profile of Percent Inorganic Matter in the Sediment Core From Lake Bruce.

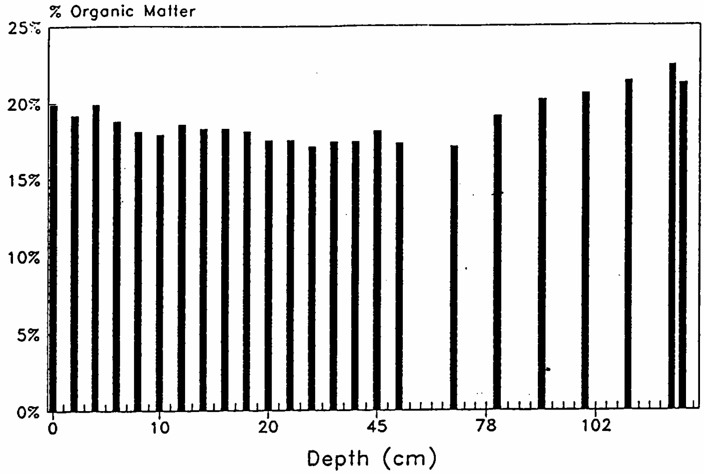


Figure 42. Profile of Percent Organic Matter in the Sediment Core From Lake Bruce.

Even though the overall percentage variation was not great, there was, however, a pronounced trend to the data. From a core maximum of 23% at the bottom of the core, organic content decreased progressively to 17% at a depth of 50 cm. Values remained reasonably constant throughout upper 50 cm of the core including the most recently deposited sediments. It is indeed unusual to find such highly inorganic sediments in eutrophic lakes. Normally, one would expect greater than 80% inorganic matter in either extremely unproductive lakes (oligotrophic) or reservoirs receiving heavy sediment loads from upstream. Such a finding at Lake Bruce is a clear indication of the extent of watershed erosion and deposition of inorganic material in the lake and supports our earlier assertion that the volume of the lake has been reduced approximately 25% in the past 34 years. It is normal for eutrophic Indiana lakes to deposit in excess of one meter of sediment in one hundred years (Crisman 1987). The slight variability in the percentage of inorganic and organic matter in the 124 cm long core suggests that the relative contribution of each has changed little in the past 100 years. Such an interpretation, however, does not imply that the annual sedimentation of these parameters has remained constant for the past century. Given that no charge was included for 210-Pb dating in our budget and this parameter was to be used only if a pronounced stratigraphy was noted, we have not included such a dating technique. Instead, we have relied on indirect estimation of sedimentation in Lake Bruce via comparison of current and historical bathymetric maps and the extent of recent basin infilling.

In situations such as Lake Bruce where the percentage of inorganic and organic matter does not change appreciably along the length of a sediment core, it is conventional to express total phosphorus concentrations as a function of the total dry weight of sediment at a particular depth in the core. In this way, deviations in the total phosphorus to sediment dry weight ratio can be used to delineate periods of past phosphorus enrichment in the lake (Figure 43). Although a great deal of intracore variability was noted, it appears that there has been a slight reduction in the total phosphorus to sediment dry weight ratio in the most recently deposited sediments (0-18 cm) compared to earlier periods.

The relationship between total phosphorus and sediment organic matter percentage for the Lake Bruce core is presented in Figure 44. The two parameters display similar trends along the length of the sediment core suggesting that phosphorus is entering Lake Bruce in a form that is easily utilized for algal and macrophyte growth.

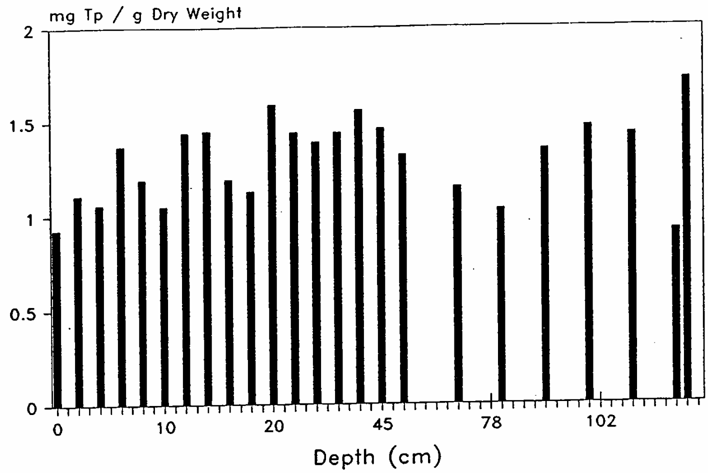


Figure 43. Profile of Total Phosphorus Concentrations in the Sediment Core From Lake Bruce.

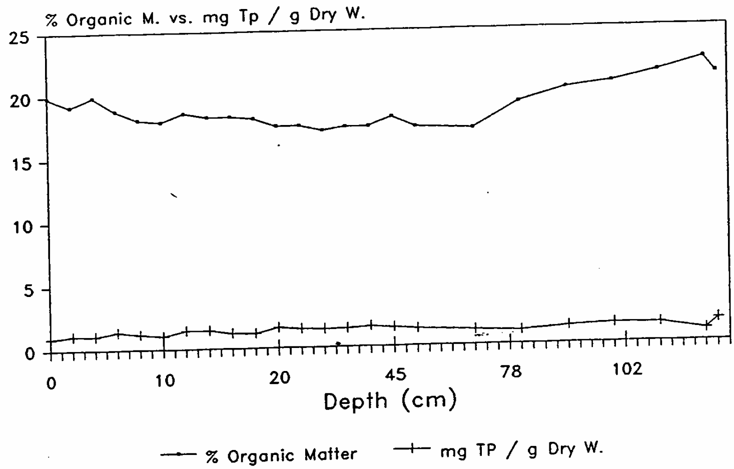


Figure 44. Comparison of Profiles of Organic Matter Percent and Total Phosphorus/Gram Sediment Dry Weight for the Sediment Core From Lake Bruce.

The Watershed 2.

The Watershed

The approach of this part of the study is to specifically address the effect of the watershed on the Lake. After preliminary investigation, the method was to target the area(s) of highest concern. The task was to build upon the 1983, Watershed Protection Plan for Bruce Lake Watershed by the Fulton County SCS, Fulton County Drainage Board and the Lake Bruce Association. The study is quite extensive regarding watershed land-use and erosion, but had only general observations about the lake. Basically, our study had to start from the beginning to discover how this watershed was contributing to challenges in this lake system. The concerns to be identified in the watershed were as follows:

a. Nutrient contribution to the Lake;
b. What are the probable sources;
c. How much sediment is coming into the Lake;
d. How can sediment be reduced;
e. What are the intrinsic values of the watershed, and
f. How can the sources of sediment/nutrients be reduced from affecting the lake?

This feasibility study included the use of the following resources:

a. Reconnaissance of the entire watershed by site visits on several occasions;
b. Walking tours of some private property areas that could not be properly observed from public areas;
c. Aerial photographs (County Surveyor);
d. Aerial photographs (USDA - Soil Conservation Service, 1966 and 1978);
e. Aerial color infrared photographs (NAPP, 1981);
f. United States Geological Survey (USGS) map, Kewanna Quadrangle;
g. United States Fish and Wildlife Service, National Wetland Inventory map, Kewanna Quadrangle;
h. USDA - SCS Soil Surveys of Fulton (1987) and Pulaski (1968) Counties Indiana;
i. Fulton and Pulaski County records: Auditor, Surveyor, Treasurer, etc:,
j. Various meetings and/or telephone conversations with State & County agencies, local property owners and;
k. Engineering reconnaissance by ESI to determine suitability of potential target sites.

The main purpose of this investigation was to target the area(s) which would be the highest priority(ies) for land treatment systems for trapping nutrients and sediments in the watershed. These constructed solutions may consist of settling basins, constructed wetlands, sediment traps, ponds, or shallow water habitat areas, etc. These terms are descriptive of similar broad-scale land treatment concepts that would reduce nutrient and sediment loading to the Lake Bruce system. Other upland agricultural practices such as terracing, grassed waterways, conservation tillage, and proper animal waste disposal are all vital methods to improving the water quality of the lake. These practices, however, are largely beyond the direct control of the Lake Association and are considered beyond the scope of this study. Local SCS and ASCS offices have been appraised of the areas felt to be contributing excessive amounts of sediment and nutrients or that would otherwise benefit from programs beyond the scope of the Lake Enhancement study. The goal of this feasibility study is to focus on the site(s) of greatest potential; to most benefit the lake system in the shortest time; and to attempt to identify the process to create this system and its costs. The final considerations that would evaluate the feasibility and/or priority of such constructed projects would then be up to the Lake Association leadership. Discussions with Mr. Dan Rosswurm at the Fulton County Soil Conservation Service office indicated the awareness of problems with soils and agricultural practices above the lake. The SCS has pledged to help the Lake Association in any way possible including technical support, and initiating discussions with owners of properties which are contributing intolerable amounts of sediment, nutrient, and animal waste runoff. The SCS would be important support on the larger constructed solutions, and could be of prime responsibility to encourage and/or design the other upland practices and structures. Field reconnaissance by **Earth Source Inc.** in early spring 1989 noted that some changes had occurred in the watershed since the 1983 report. Particularly in the northern third of the watershed (northeast of the lake), an apparent combination of economic factors, change in cropping practices, and natural evolution of land conditions has taken place. This "evolution of land conditions" can be a very complex cause-effect relationship. For example, the filling of the lake by sediment can further affect adjacent soil conditions, making these soils more saturated and difficult to drain. Also, subsidence ("sinking") of organic soils that were drained for farming has again returned some land to wetland or problem areas to farm.

Watershed impressions by visual survey

The purpose of this section is to express in narrative form the observations and general visual impressions that were made during site tours of the watersheds and review of color infrared and other aerial photographs. The intent is to provide a perspective that may be fresh and to stimulate residents to make their own continuing observations.

Prior to our detailed watershed tours, we examined several aerial photographs of the Lake and watershed. The purpose of this was to identify potential problem areas not likely to be observed from the ground inorder that they could be checked in the field. Aerial photographs were also used to help us focus in on the "big picture". This allowed us to understand the watershed interaction as a whole before we broke it down into its smallest components.

Lake Bruce and its watershed

The following discussion will be presented as organized by subwatersheds (approximately), going clockwise from the north side of Lake Bruce (Figure 45).

Frasa Subwatershed:

1. This area is very close to the lake, which makes it very critical to investigate the possible sediment/nutrient sources to the lake. Review of aerial photographs indicate a large delta forming at the Frasa Ditch inlet. This delta was not as pronounced 20 or even 15 years ago. Our visual survey also noted large quantities of sediment in the channel, in excess of 6 foot of unconsolidated material.

2. A dairy-type animal lot (An). Possible nutrient source. Some erosion in short pasture.

3. Bottom land field was open ditched for crop farming (prior to 1981). Appears that less than one-half currently farmed...still too wet? Ditch bank erosion probably also a factor as well as release of nutrients in organic soil.

4. The 'bottom land' is ringed with naturally occurring steep slopes with highly erodible land (HEL) appearance. Upland above this also erodible? But small area...

Overmyer Ditch Subwatershed:

1. At the northern edge of the watershed are several hundred acres of fragile land which includes forested (Fo), wetland (Wt), and hay/grass/pasture (Gr).

This area appears to have been recently addressed for conservation practices, i.e. to hay/grass instead of row crops. However, these practices and the conservation of the wooded area needs to be preserved. To drain the woods is unnecessary, for example. There is still probably a significant natural export of sediment from this area.

2. At the northeastern edge are flat areas that appear to be intercepted by depressions- non-contributing (N/c). Some land is in conservation tillage.

3. From the inlet into Lake Bruce to over one mile east, there is very little change in the drainage gradient. The land next to this ditch has wide flat areas that appear difficult to farm due to saturated soils. Nearer the lake, this "upland" is very close to lake level. This presents excellent constructed wetland (Cw) opportunities from ten to forty acres. This proximity to the lake would intercept almost the entire 2889 acre drainage area, including critical inflows from the north and other highly erodible lands. (see also HEL map).

4. Several large tracts of recently seeded Conservation Reserve Program (Crp) land occur along the ditch in critical areas. (see also, HEL map).

5. A very attractive wetland (Wt) area occurs at the southeast corner of 125N and 1050W. It is apparent that a very small portion of the watershed (about 50 acres) flows through this wetland. It was also noted that the northern perimeter of the wetland has been ditched.

6. On the east side of State Road 17 is a cattle lot (An). This area should also be investigated for an upland constructed option (Cw), e.g. grass filter strips.

7. The land east of State Road 17 is primarily in grain production and is therefore highly fertile.

Bruce Ditch Subwatershed:

1. A small open ditch not recently 'cleaned', there is a natural trap (Wt) on the east side of 1100W that is intercepting much of this drainage area. Save and enhance this area! A tile (Bruce tile) was observed entering the lake to the north of this wetland. A water sample from this tile revealed it was carrying a very high nutrient load. Could this tile be intercepted to flow through the wetland to the south?

2. The channels at the southeast corner of the lake indicate high fertility. Some of this is entering through drain inlets. Divert these drains to existing or new wetland filter...?

3. Review of aerial photographs indicate a delta forming at the Baker Ditch inlet. This delta was not observed in aerial photos taken 10 years earlier. Can the wetland east of 1100W be enhanced to impede this flow of sediment to the lake?

<u>Baker Ditch Subwatershed:</u>

1. The ditch is loaded with organic sediment from pumped (Pump) cropland south of the lake. Some of this material may be attributed to slumping organic ditch banks. High fertility is obvious.

2. Animal lots (An) occur on both sides of the ditch north of 75N. These lots appear to be somewhat cleansed by grassed filter strips and the wetland to the east of the ditch. These areas could be readily intercepted by improving the wetlands (Cw) and, at the same time, treat the balance of the drainage area.

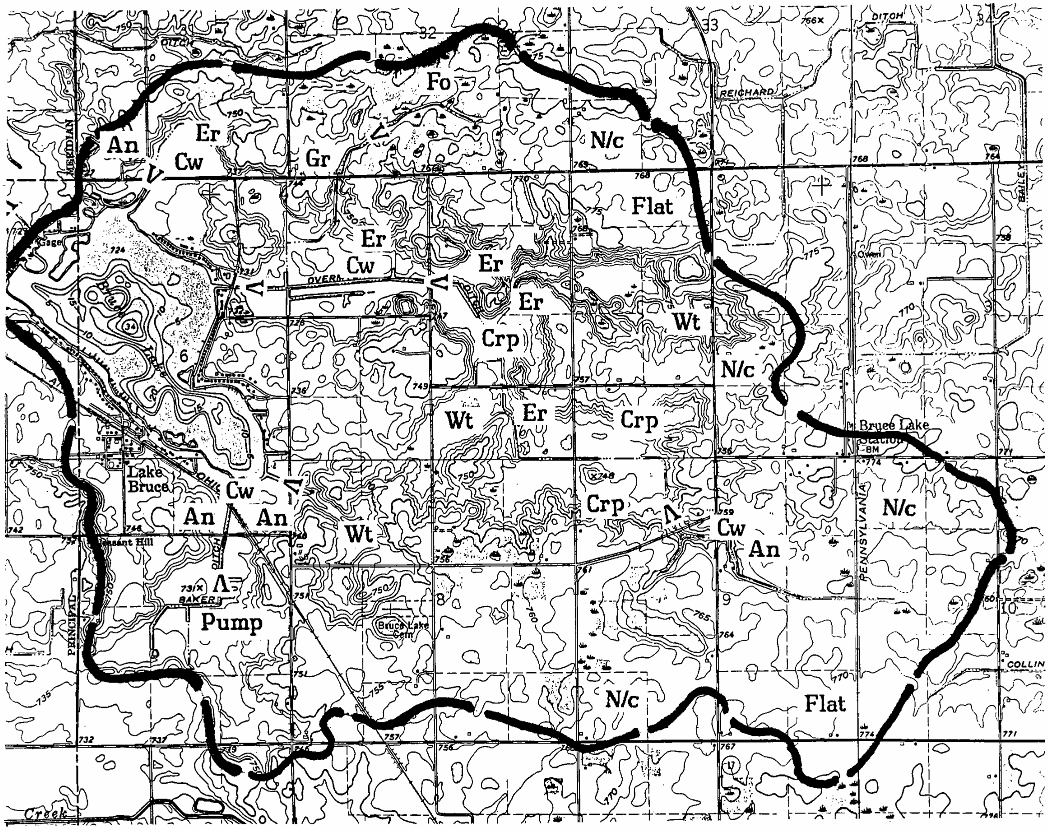
3. The stream survey of the Baker Ditch noted isopods as a significant part of the benthic community. Isopods can be a good indicator of highly productive (nutrient rich) waters with abundant amounts of dissolved organic solids. High fertility is obvious.

<u>Lake Bruce Shore:</u>

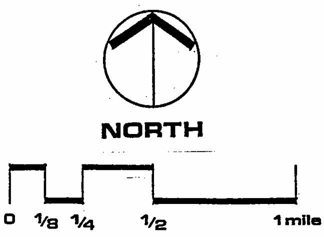
The southwest shore of Lake Bruce is heavily developed with a mix of small permanent homes and older summer cottages. Some buildings and homes appear to be abandoned. This area may be suspect for the age and efficiency of household waste disposal. The abandoned railroad bed may also be a source of various pollutants.

The north shore is more recently developed, as is the east shore. Both of these shores are developed at levels near the lake elevation on made land or hydric soils. (see also Septic System Study). The north shore still has some good lake edge that should be preserved.

LAKE BRUCE WATERSHED TOUR



Legend



N/c	Non-contributing
An	Animal operations
Cw	Possible constructed option site
Wt	Wetland
Er	Appears erodible
Fo	Forested/wetland area
Gr	Grassland
Flat	Relatively flat land
<	Flow direction
Crp	Land in conservation reserve program
	Watershed boundary

Figure 45.

Photospectroscopy

Aerial photography is an intricate tool for use in many topographic and natural resource applications.

In doing a land use study using aerial photography, several items must first be considered to provide the most accurate detailed information possible in obtaining the desired data.

First, and probably most important in doing a study of primarily agricultural usage, the "type" of photograph used is important. For the most part, two "types" of photographs exist: 1) those taken in the visible spectrum, and 2) those taken in ultraviolet or infrared spectrum of light. Since all living organisms emit energy in the electromagnetic spectrum and since our study is based primarily in an agricultural and watershed area, color infrared photography was used.

This type of photography delineates plants through size, density, and respiration, by photographing specific intensities of electromagnetic radiation emitted. Fallow lands, lake and wetlands appear as grey or black areas on the photo.

Second, the date in which the photographs were taken is an important consideration in the determination of the results and comparison to current trends.

Month and day play a factor in the interpretation of the types of vegetation and wetlands described. An extreme example of this would be trying to distinguish agricultural usage on a photo taken in July compared to the same photo taken in December. The day is also a factor because of previous weather conditions. The photographs used for this study were taken on the May 2, 1981 fly-over at a scale of 1:60000 (Figure 46).

In doing the study of Lake Bruce, the entire watershed was laid out on the photographs using a transparency, and then divided into respective sub-watersheds. The size of an overlay grid (1 acre) was then calculated, drawn, and then placed over the photos. From there, each sub-watershed was divided into the following land use categories:

- Forested (woodlots)
- Agriculture -active (winter wheat)
- Agriculture -other (corn, soybeans)
- Pastureland (hay, alfalfa, oats and tilled lands)
- Wetlands
- Residential
- Lake Bruce

Land use is graphically represented in Figure 47.

Figure 46. 1981, color infrared aerial photograph of the Lake Bruce watershed. Overlapping photos were viewed using a stereo scope to determine land use.

Tabulated results are shown in Tables 12 and 13, and are divided into watershed and sub-watershed categories. Additional graphical representation of each land use category is shown according to each sub-watershed, and the entire area as a whole (Figures 48-52) Percent representation of each category compared to the entire watershed category is shown in Figure 53. The margin of error in watershed acreage determination was 0.1% of the USDA Bruce Lake survey. This margin falls well within the boundaries of accuracy for a 1:60000 scale. Those results given are results as of 1981 information.

Due to the time frame of the photographs, classification of the agricultural subdivisions may be skewed to one class or another, however, overall determination of agricultural usage is accurate.

Climatological data for Indiana during April and May of 1981 indicates that the average monthly precipitation for this time period was 4.23 and 3.44 inches above normal, respectively. Interpretation of this data, in conjunction with the aerial land-use study may over emphasize the amount distributed to the wetland category. Major wetland depressions were cross checked against the National Wetland Inventory maps for accuracy.

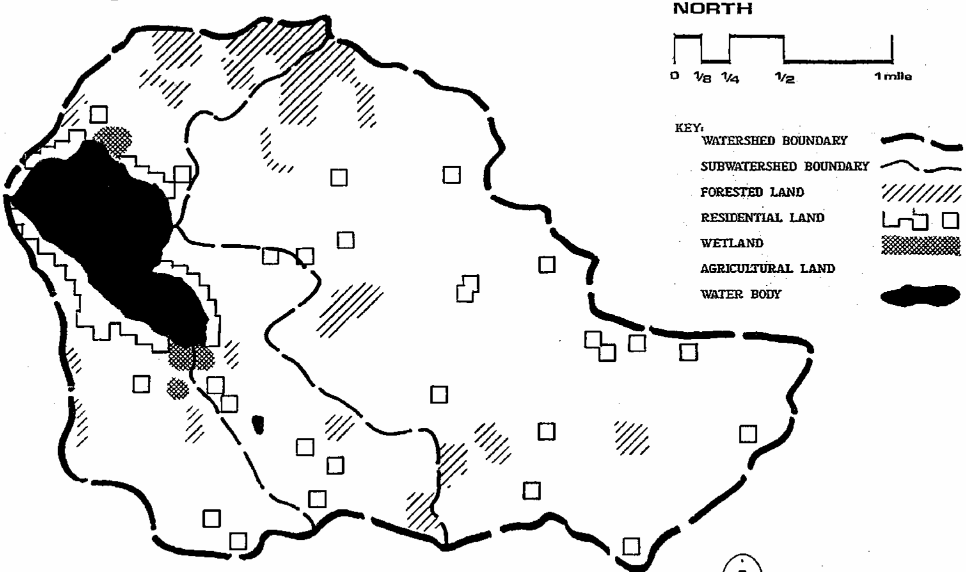
Aerial photographs are also examined for current prominent erosion or deposition sites. The results of this examination can direct some target site selection and priority considerations.

Land Use Trends

Historically, there have been few major changes in land use in the Lake Bruce watershed. The main land use in the Lake Bruce watershed is agricultural, there are about 60 farms, with an average size of 60 acres. Minor shifts in the type of agricultural land use have been frequent due to the varying demands of the world market. Wetlands have witnessed the greatest decline due to drainage. The past 25 years have seen the conversion of about 70 acres of forested land to cropland. The seventies and early eighties indicated a trend to convert pasture and grasslands to cropland, primarily due to declining livestock prices and fluctuations in grain prices. The areas effected most by this change were lands with severe slopes that previously had been in pasture were being converted to row crop. Current and projected trends in the Lake Bruce watershed are to enlist more low production non-prime agricultural land to CRP type and land treatment programs. This will likely increase the amount of forestland and wetland throughout the watershed. This is a reflection of the HEL provision of the 1985 farm bill that calls for highly erodible fields be farmed with conservation methods in order for the operator to be eligible for government programs.

LAKE BRUCE WATERSHED LAND USE MAP

Figure 47.



WATERSHED BOUNDARY SOURCE: DNR DIVISION OF WATER

Earth·Source Inc

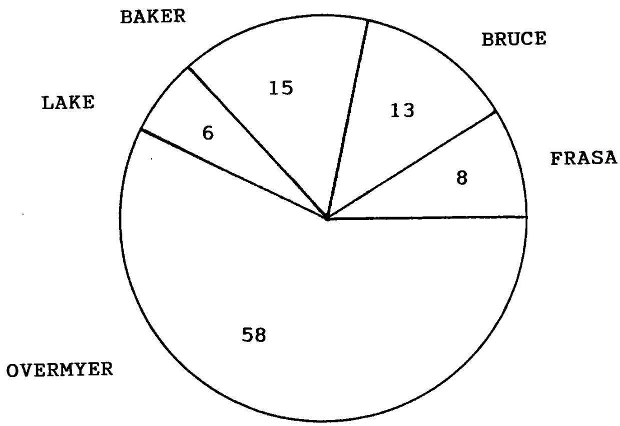
349 Airport North Office Park, Fort Wayne, IN 46825 (219) 489-8511

WATERSHED CHARACTERISTICS	
Total Watershed Area (acres)	4078
Drainage Area (acres)	3813
Agriculture -active	474 (12%)
Agriculture -other	642 (16%)
Pasture (hay & tilled lands)	2188 (54%)
Forest	211 (05%)
Wetlands	179 (04%)
Residential	119 (03%)
Lake Bruce	265 (06%)
HEL	28 (<1%)
Potential HEL	575 (15%)
Basin Slope (m/km):	3.36
Channel Slope (m/km):	
Baker Ditch	1.44
Bruce Ditch	3.08
Frasa Ditch	3.38
Overmyer Ditch	2.58
Precipitation (in/yr):	
Mean	37.0
Standard Deviation	8.7

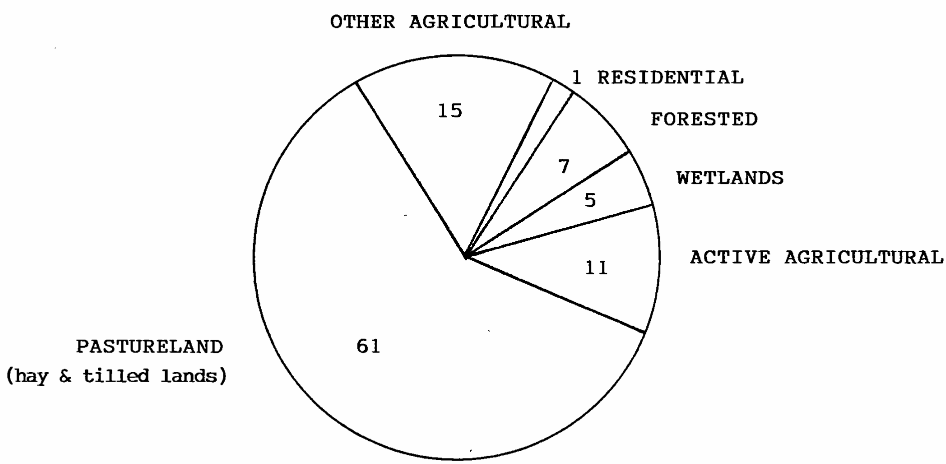
Table 12. Characteristics of the Lake Bruce watershed, May 2, 1981.

LAND USE	BAKER	BRUCE	FRASA	OVERMYER
Agriculture -active	59	95	56	264
Agriculture -other	110	46	126	360
Pastureland (hay & tilled lands)	365	341	44	1438
Forested	6	10	31	164
Wetland	4	25	34	116
Residential	63	30	15	11

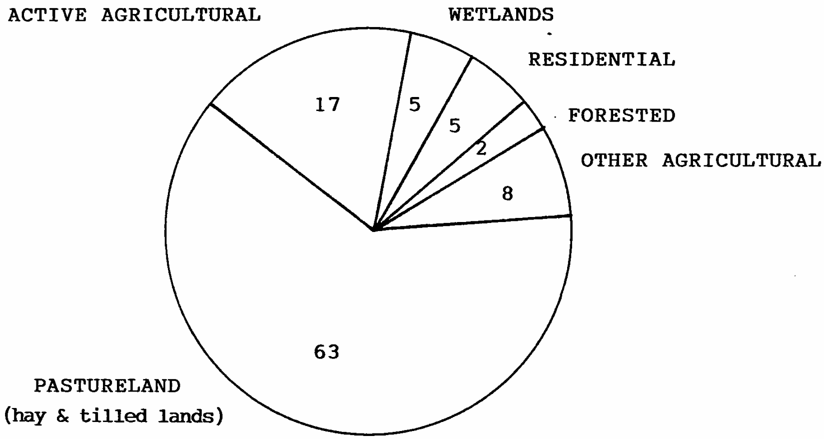
Table 13. Land use distribution (acres) by sub-watershed.



SUBWATERSHED
DISTRIBUTION BY PERCENT
(FIG. 48)

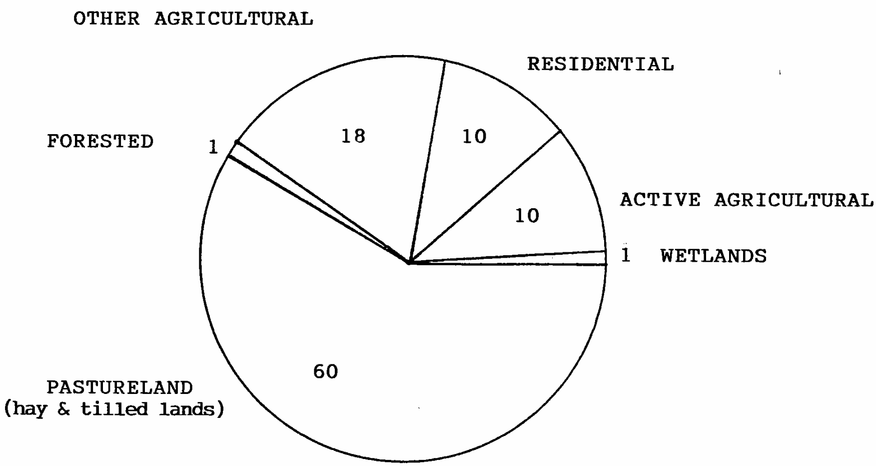


OVERMYER DITCH
LAND USE DISTRIBUTION BY PERCENT
(FIG. 49)



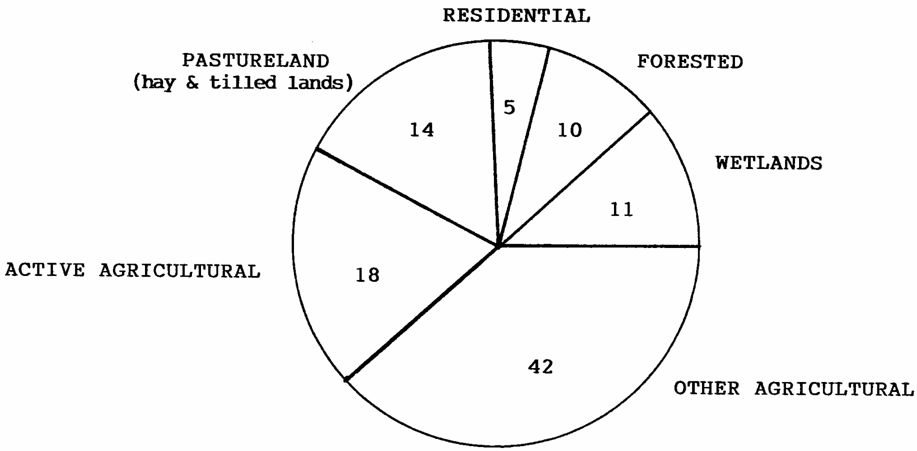
BRUCE DITCH

LAND USE DISTRIBUTION BY PERCENT
(FIG. 50)



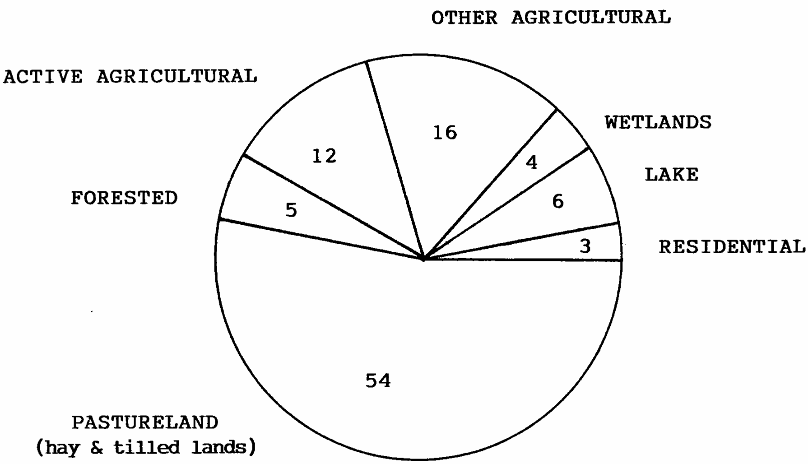
BAKER DITCH

LAND USE DISTRIBUTION BY PERCENT
(FIG. 51)



FRASA DITCH

LAND USE DISTRIBUTION BY PERCENT
(FIG. 52)



LAKE BRUCE
LAND USE DISTRIBUTION BY PERCENT

Figure 53.

Topography

The watershed of Lake Bruce is best described as a morainal topography. The highest point in the Lake Bruce watershed is 775 feet above sea level and the lowest point is 690 feet above sea level. The average elevation in the Lake Bruce watershed is approximately 750 feet.

Relief throughout the watershed is characterized as somewhat depressional near the lake, moderately sloping over the central region to nearly level in the upper portions of the watershed. Slopes range from 0 to 18 percent.

Severe slopes

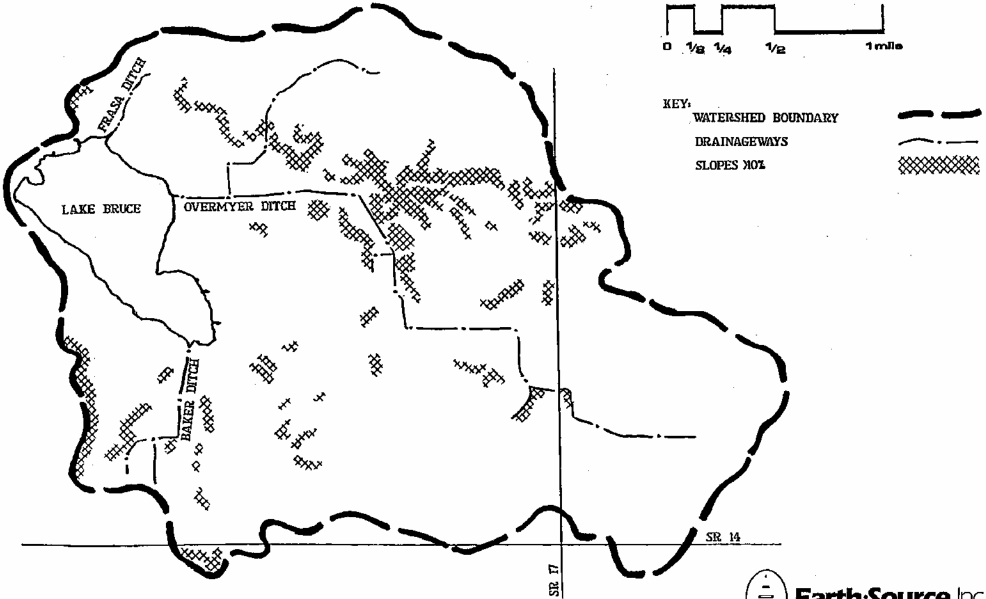
The length and steepness of slopes are major factors in assessing the probable erosion risks of an area. On steep or long slopes, runoff water accumulates in channels where increased flows produce greater erosive forces. Level or flat lands produce shallow overland flows over a larger area. This decreases the erosive forces of runoff.

The intent of this study-map (Figure 54) is to further illustrate the fabric of the land forms in the watershed. Areas with severe slopes comprise 251 acres of the Lake Bruce watershed. Severe slopes in detailed in this study range from 10 to 18 percent. This study provides further evidence where the study emphasis should be. This graphic also substantially matches the worst conditions of Highly Erodible Lands and will be discussed further later in the report.

In general, areas mapped as having severe slopes should not be in agricultural crop production or should be in a conservation tillage program, as is the case along much of the Overmyer Ditch. Some of these sloped areas are also too steep for development without special care, if at all.

LAKE BRUCE WATERSHED
SLOPE STUDY

(Figure 54)



WATERSHED BOUNDARY SOURCE: USGS, NATURAL BOUNDARY

Earth·Source Inc

Geology

The first intrinsic value of any watershed rests in an understanding of the underlying geology, the base from which a watershed is built. The Lake Bruce watershed is underlain by bedrock of the Wabash Formation. The Wabash Formation consists of limestone, dolomite and argillaceous dolomite laid down in the Mid to Upper Silurian Period of the Paleozoic Era (421 to 428 million years ago).

The Wabash Formation in the Lake Bruce area is covered by over 200 feet of partially lithophied to unconsolidated glacial deposits. The most recent glaciation occurred some 12,000 years ago during the Wisconsinan Advance. The Lake Bruce watershed is comprised of sediments deposited from the Huron-Saginaw Lobe of the Wisconsinan Ice Sheet. This material is dominated by an outwash association of sand and gravel fan deposits. More complex till of the area consists of stratified drift in chaotic form. This makes up the clay-loam to silt-loam till of the Wedron formation. For further discussion on surface geology, see Soils.

Soils

The soils of the Lake Bruce watershed are grouped in the Markton-Metea Association (Figure 55) by the Fulton County Soil Survey. This association is further characterized as nearly level to moderately sloping areas along drainageways and small knolls and ridges.

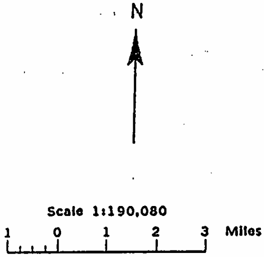
The association is approximately 35 percent Markton and similar soils, and 30 percent Metea soils, and 35 percent minor soils.

The somewhat poorly drained, nearly level Markton soils are on broad lake and till plains. Typically, they have a surface layer of very dark grayish brown loamy sand and a subsoil of yellowish brown fine sand; dark brown, mottled loamy sand and sandy loam; and grayish brown fine sandy loam.

The well drained, nearly level to moderately sloping Metea soils are on low knolls and side slopes on moraines and till plains. Typically, they have a surface layer of dark brown loamy sand, a subsurface layer of yellowish brown loamy sand and a subsoil of dark yellowish brown fine sandy loam.

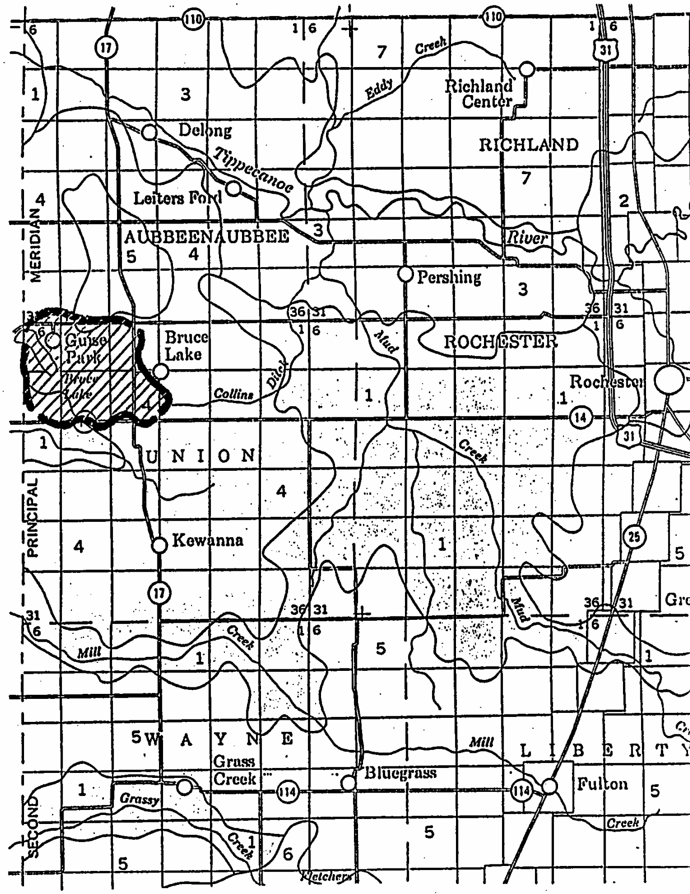
The Minor soils in this association are the excessively drained Chelsea and Plainfield soils on ridges, the poorly drained Barry soils in depressional areas and along poorly defined drainageways, and somewhat poorly drained Crosier soils in nearly level areas.

(source: Fulton County Soil Survey)



GENERAL SOIL MAP

Figure 55.
Adapted from the
Fulton County Soil
Survey



The shaded area indicate soils of the **Markton-Metea** association: Nearly level to moderately sloping, somewhat poorly drained to well drained soils formed in sandy material overlying loamy glacial till.

Highly Erodible Land (HEL)

The purpose of identifying areas containing HEL is to display the origin of potential sediment sources so that the study may target areas of general concern. Using the Soil Survey of Fulton and Pulaski counties by the USDA-SCS issued in 1987 and 1968 respectively, and data provided by the local SWCD and SCS offices, soils of the HEL designation were mapped as shown in Figure 56.

The following highly erodible soils occur within the Lake Bruce watershed (Table 14).

Kosciusko-Ormas complex, 2 to 6% slopes **
Kosciusko-Ormas complex, 6 to 12% slopes**
Metea loamy sand, 6 to 12% slopes **
Morley loam, 2 to 6% slopes **
Plainfield sand, 6 to 12% slopes **
Riddles fine sandy loam, 2 to 6% slopes **
Riddles fine sandy loam, 6 to 12% slopes **
Wawasee fine sandy loam, 2 to 6% slopes **
Wawasee fine sandy loam, 6 to 12% slopes **
Wawasee loam, 12 to 18% slopes *

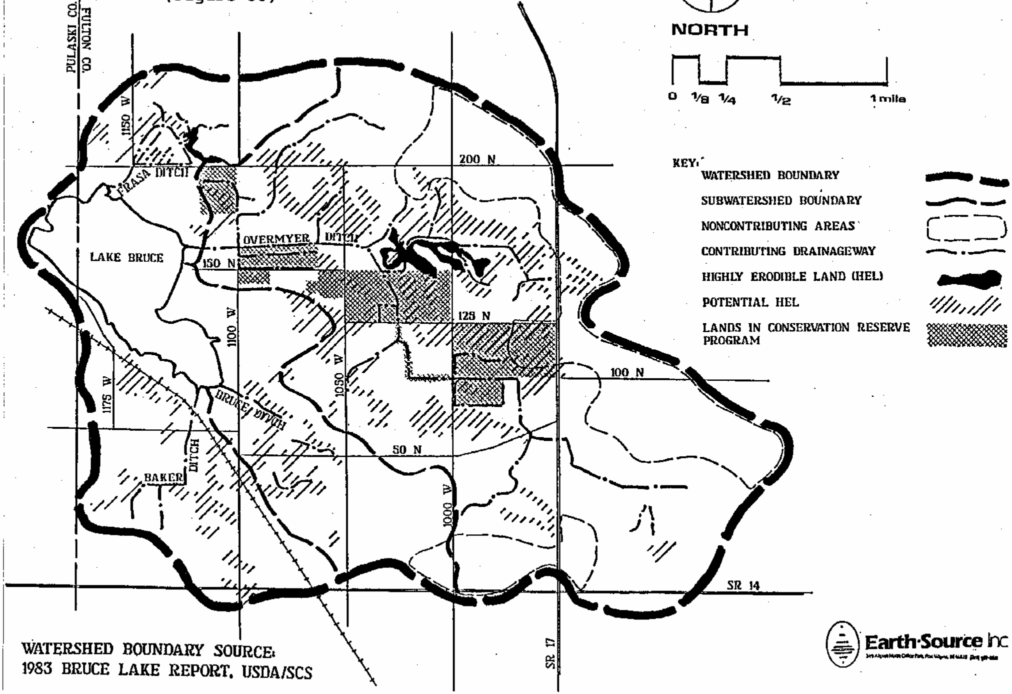
* Highly erodible land
** Potentially highly erodible land

Table 14. **HEL and Potential HEL soils of the Lake Bruce watershed.**

The Lake Bruce watershed was broken down into subwatersheds to determine the extent of HEL map units and/or potential HEL (HEL) in each subdrainage area. The Overmyer subwatershed, (the largest at 2328 acres) contains 415 acres of HEL, 18% of that subwatershed. The 601 acre, Baker subwatershed contains 11% HEL (65 acres). The Bruce subwatershed, at 529 acres contains 94 acres or 18% of HEL. Finally, the Frasa subwatershed, at 307 acres contains 30 acres or 10% of HEL. HEL or potential HEL was found to comprise 16.0% (apx 603 ac) of the Lake Bruce watershed. The study area was then further divided to determine the extent of contributing and non-contributing HEL. Approximately 95% (575 ac) of the total HEL are considered to be directly contributing to Lake Bruce. The HEL study was based strictly on HEL map units, it does not take into account non-HEL map units which may have inclusions of HEL soils. Estimates of HEL and non-HEL with HEL inclusions are in excess of 1,500 acres or 37% of the watershed. Target sediment sources were located using the HEL map and aerial photos, and will be discussed further in the recommendations and conclusions section of this report.

LAKE BRUCE WATERSHED STUDY

HIGHLY ERODIBLE LAND (HEL)
(Figure 56)



WATERSHED BOUNDARY SOURCE:
1983 BRUCE LAKE REPORT, USDA/SCS

HEL/Severe slope overlay

The intent of this overlay (Figure 57) is to further emphasize the areas of the watershed where severe erosion problems are likely to occur. The majority of the areas defined in the HEL/severe slope overlay are adjacent to open ditches which facilitate the transport of eroded soils to the lake. For this reason, those areas present the greatest sedimentation threat to Lake Bruce. Every effort should be made to enlist those lands into CRP or related land treatment programs. It must be noted that about half of the critical erosion areas of the Overmyer Ditch subwatershed are in CRP. This is a good start, but it is painfully apparent from the HEL/severe slope overlay that the majority of the critical erosion areas of the watershed have not been fully addressed. The upper reaches of the Overmyer Ditch, Baker Ditch, Bruce Ditch, and Frasa Ditch all contain lands where critical erosion problems are likely to occur. These lands should not be in agricultural crop production.

Erosion: Causes and Prevention

Erosion of soil is primarily caused by the force of raindrops striking the ground, and, secondly, by the force of water flowing in rills or channels. As rain falls on unprotected ground it breaks small particles of soil free. These soil particles are then carried away by sheets of water. Naturally, as the intensity of rainfall increases, velocity and volume (flow) of runoff increases, thus potential soil erosion increases.

Types of soil erosion probable or noted in the Lake Bruce watershed:

1. Raindrop (or splash) erosion due to the impact of rain on unprotected land.

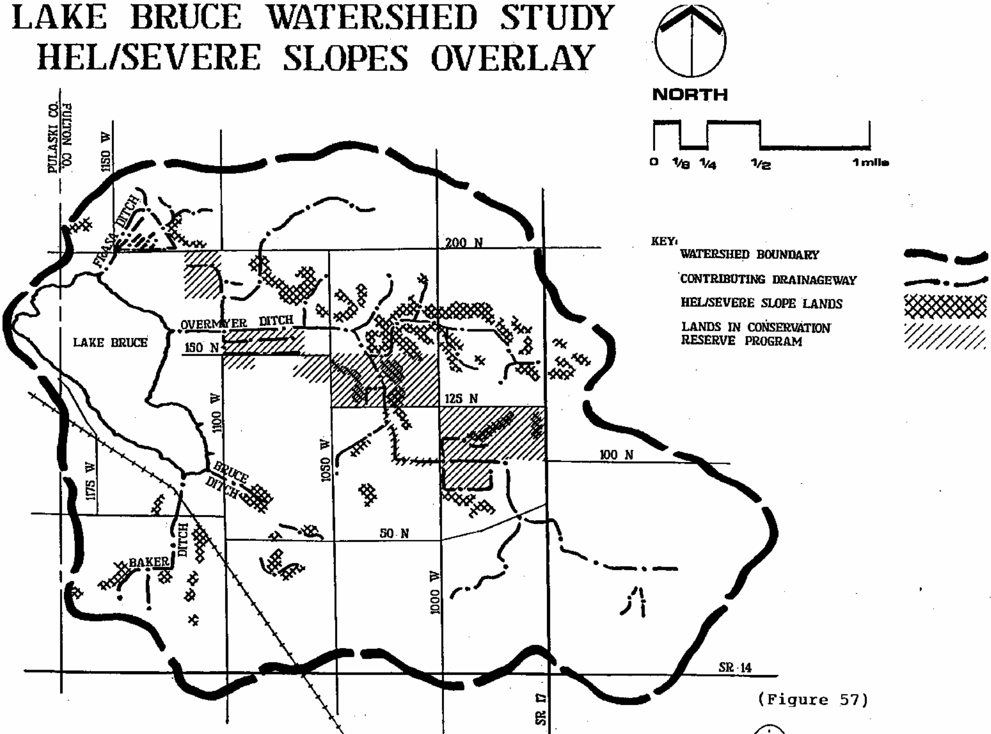
2. Sheet erosion or overland flow causes exposed soil to be suspended by the action of the flowing water, this is common on sloping to nearly level unprotected land.

3. Rill and gully erosion is the result of concentrations of runoff water in riverlates. Rill erosion may cut several inches into the topsoil, gully erosion resulting from unmaintained rills or drainages may cut several feet into the surface.

4. Streambank and channel erosion causes a scouring of stream bottom and undercutting of stream banks.

5. Wind erosion, similar to sheet erosion, is caused by the turbulent force of the wind over unprotected land.

LAKE BRUCE WATERSHED STUDY
HEL/SEVERE SLOPES OVERLAY



(Figure 57)

Earth·Source Inc

The erosion potential of a given area may be determined by four criteria: 1) soils; 2) surface cover; 3) topography; and 4) climate.

An understanding of soils, and the factors involved in making soil more susceptible to erosion include: soil texture, soil structure, soil content of clay or organic material, and soil permeability. Maintaining adequate surface cover, either in the form of vegetative cover or crop residue, is important in reducing soil loss.

The realization is that soil is a valuable resource, and particles are difficult and expensive to recover once erosion has begun.

Prevention is easier than correction!

Useful concepts in erosion prevention and control:

a. Maintain natural vegetative cover wherever possible.

b. Protect sloping areas. Vegetation is difficult to establish and maintain of eroded slopes.
Row cropping should be done perpendicular to slope.

c. Divert runoff from severely sloping areas.

d. Break up long slope lengths by multiple cropping or landscaping when natural cover is not maintained.

e. Stabilize drainage areas immediately following any construction or "maintenance".

f. Leave natural buffer areas along streams and ditches.

g. Stabilize stream bank or ditch escarpments.

h. Utilize sediment ponds below feed lots and "open" sloping lands.

i. Construct and maintain sediment control structures <u>prior</u> to construction of any lake or waterfront development.

Development on Saturated Soils

The goal of this study was to estimate potential septic system inefficiencies. Ineffective septic systems have been documented to contribute excessive amounts of nutrients to a lake and likely share in the cause of a poor overall water quality rating. Using data collected on saturated soils (Table 15) and comparing it with building records from 1962, projections were established indicating septic systems that were likely to be located in saturated soils (Figure 58).

The assumption was made that septic tank-type systems are in place for those residences located on saturated soils. General septic system efficiencies are based on the need for well drained soils necessary for proper treatment of sewage effluent. The raw sewage is decomposed by organisms requiring aerobic respiration, thus requiring well drained soils. It should be noted that seasonal fluctuations in the water table of poorly drained soils were not taken into account. Varying water table elevations and waste loading would be responsible for fluctuations in treatment success. Localized fecal coliform values likely increased due to a substantial increase in the summer population around the lake and fluctuations in the water table as well as residences in the watershed with septic systems that outlet directly into ditches.

The findings of this study indicate a definite trend towards building on saturated soils. In 1962, on Lake Bruce, 137 of the 160 homes (86%) were located on saturated soils. Although current building records for Lake Bruce were not available at the time of this study, aerial inspection has shown an overall increase of residences situated on poorly drained soils.

Possible approaches to meet the current or future disposal needs with the objective of maintaining or improving water quality would include: 1) Lake-wide sanitary sewer system, 2) mound type septic systems and/or 3) pumping to suitable septic locations and 4) any of the above in combination with a constructed wetland or pond/wet meadow system.

The first, likely most effective and costly method of waste handling would entail the construction of a lake community-wide sanitary sewer system with off-site waste treatment. The second method, a mound type septic system would involve raising the septic tank and drain field above the saturated soil allowing for aerobic treatment of the sewage effluent. The third method of waste treatment, is a procedure which involves pumping the waste effluent to an area with soils suitable for use in septic tank systems.

Although treatment is certainly not limited to the management approaches discussed above, it was determined that these methods of waste treatment would effectively meet the goals of sewage disposal.

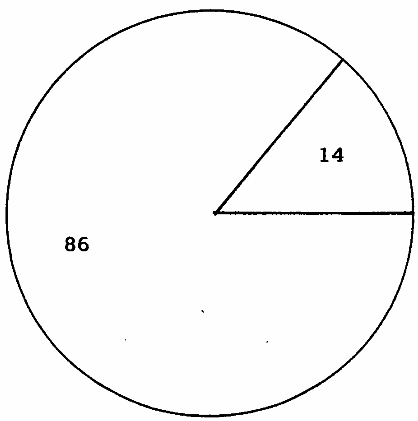
Residences must take on the responsibility of maintaining their own waste disposal systems. Drain fields should be inspected regularly and septic tanks should be pumped on a regular schedule.

If it is determined that an engineering study should be undertaken for a new wastewater treatment system, the method and site selection should consider tertiary treatment using a constructed wetland system.

Table 15. **Poorly drained soils adjacent to Lake Bruce.**

BARRY loam
BROOKSTON loam
GILFORD fine sandy loam
GILFORD fine sandy loam, Loamy substratum
MARKTON loamy sand
WASHTENAW silt loam

Figure 58. **Profiles of Residences Located on Saturated Soils; Trends based on 1962 building records.**



Hydrology

The Lake Bruce watershed is a sub-drainage basin to the Wabash River Basin. According to the Fulton County Soil Survey, the main water supply comes from ground water (Wisconsin till aquifer). The watershed of Lake Bruce receives an average annual precipitation of 37.0 inches with a standard deviation of 8.7 inches. June tends to be the wettest month with an average precipitation of 4.4 inches. On average, January is the driest month with a precipitation mean of 1.5 inches. The greatest basin drainage gradient in the watershed is 3.36 m/km. Channel gradients range from 3.36 m/km in the Frasa Ditch to 1.44 m/km in the Baker Ditch. According to the 1979 Cowardin et al classification system, water regimes range from temporary to permanent (Tables 16-18-20-22). Forty six percent of the wetlands located in the Lake Bruce watershed are of seasonal water regimes. Ninety three percent are small, less than ten acre, palustrine wetlands (Tables 17-19-21-23) (reference Table 12). Palustrine defined here as wetlands less than 20 acres in size, averaging less than 6 foot in depth, and dominated by trees, shrubs, and/or emergent vegetation (Mitsch and Gosselink, 1986).

> **The past ten years have witnessed an extraordinary revival of interest in the drainage and reclamation of our non-arable swamp lands, and it is safe to predict that no movement will be attended with more beneficial or far reaching consequences.**

1914 "Drainage and Reclamation of Swamp and Overflowed Lands" Bulletin No. 2, Indiana Bureau of Legislative Information

It is estimated that 88% of the wetlands in the Wabash River Basin have been lost (Hamilton 1965). Losses are primarily attributed to drainage for agricultural production. The following tables are intended to illustrate the types of wetlands remaining in the Lake Bruce watershed, and focus attention on preserving these natural filters.

Table 16. Baker subwatershed water regime characteristics

Palustrine	Occurrence	%Totals
< 10 Acres	6	86
> 10 Acres	1	14
Totals	7	100
Type		
Forest	0	0
Emergent	7	100
Scrub / Shrub	0	0
Totals	7	100
Water Regime		
Temporary	0	0
Saturated	2	29
Seasonal	5	71
Semi-permanent	0	0
Intermittently Exposed	0	0
Totals	7	100

Table 17. Baker sub-watershed wetland classification. An explanation of wetland class may be found in appendix A.

By Class	> 10 Acres	Percent Class	Percent Total	< 10 Acres	Percent Class	Percent Totals
PFOA	0	0	0	0	0	0
PFOB	0	0	0	0	0	0
PFOC	0	0	0	0	0	0
PFOF	0	0	0	0	0	0
PFOG	0	0	0	0	0	0
PEMA	0	0	0	0	0	0
PEMB	1	14	1	1	14	1
PEMC	0	0	0	5	72	4
PEMF	0	0	0	0	0	0
PEMG	0	0	0	0	0	0
PSSA	0	0	0	0	0	0
PSSB	0	0	0	0	0	0
PSSC	0	0	0	0	0	0
PSSF	0	0	0	0	0	0
PSSG	0	0	0	0	0	0
Totals	1	14	1	6	86	5

Table 18. **Bruce subwatershed water regime characteristics**

Palustrine	Occurrence	%Totals
< 10 Acres	16	94
> 10 Acres	1	6
Totals	17	100
Type		
Forest	5	29
Emergent	10	59
Scrub / Shrub	1	6
Unconsolidated Bed	1	6
Totals	17	100
Water Regime		
Temporary	9	53
Saturated	0	0
Seasonal	7	41
Semi-permanent	1	6
Intermittently Exposed	0	0
Totals	17	100

Table 19. **Bruce sub-watershed wetland classification.** An explanation of wetland class may be found in appendix A.

By Class	> 10 Acres	Percent Class	Percent Total	< 10 Acres	Percent Class	Percent Totals
PFOA	0	0	0	1	6	1
PFOB	0	0	0	0	0	0
PFOC	0	0	0	4	23	4
PFOF	0	0	0	0	0	0
PEMA	0	0	0	8	47	7
PEMB	0	0	0	0	0	0
PEMC	0	0	0	1	12	2
PEMF	0	0	0	0	0	0
PSSA	0	0	0	0	0	0
PSSB	0	0	0	0	0	0
PSSC	1	6	1	0	0	0
PSSF	0	0	0	0	0	0
PSSG	0	0	0	0	0	0
PUBF	0	0	0	1	6	1
Totals	1	6	1	16	94	15

Table 20. **Frasa subwatershed water regime characteristics**

Palustrine	Occurrence	%Totals
< 10 Acres	18	95
> 10 Acres	1	5
Totals	19	100
Type		
Forest	4	21
Emergent	7	37
Scrub / Shrub	4	21
Unconsolidated Bed	4	21
Totals	19	100
Water Regime		
Temporary	2	11
Saturated	0	0
Seasonal	10	52
Semi-permanent	4	21
Intermittently Exposed	3	16
Totals	19	100

Table 21. **Frasa sub-watershed wetland classification.** An explanation of wetland class may be found in appendix A.

By Class	> 10 Acres	Percent Class	Percent Total	< 10 Acres	Percent Class	Percent Totals
PFOA	0	0	0	1	5	1
PFOB	0	0	0	0	0	0
PFOC	0	0	0	3	16	3
PFOF	0	0	0	0	0	0
PEMA	0	0	0	1	5	1
PEMB	0	0	0	0	0	0
PEMC	1	5	1	5	27	4
PEMF	0	0	0	0	0	0
PSSA	0	0	0	0	0	0
PSSB	0	0	0	0	0	0
PSSC	0	0	0	1	5	1
PSSF	0	0	0	3	16	3
PUBF	0	0	0	1	5	1
PUBG	0	0	0	3	16	3
Totals	1	5	1	18	95	17

Table 22. Overmyer subwatershed water regime characteristics

Palustrine	Occurrence	%Totals
< 10 Acres	62	93
> 10 Acres	5	7
Totals	67	100
Type		
Forest	25	37
Emergent	31	47
Scrub / Shrub	2	3
Unconsolidated Bed	9	13
Totals	67	100
Water Regime		
Temporary	29	43
Saturated	0	0
Seasonal	29	43
Semi-permanent	3	5
Intermittently Exposed	6	9
Totals	67	100

Table 23. **Overmyer sub-watershed wetland classification.** An explanation of wetland class may be found in appendix A.

By Class	> 10 Acres	Percent Class	Percent Total	< 10 Acres	Percent Class	Percent Totals
PFOA	1	2	1	7	10	6
PFOB	0	0	0	0	0	0
PFOC	2	3	2	14	21	12
PFOF	0	0	0	0	0	0
PEMA	2	3	2	20	30	18
PEMB	0	0	0	0	0	0
PEMC	0	0	0	10	15	9
PEMF	0	0	0	0	0	0
PSSA	0	0	0	0	0	0
PSSB	0	0	0	0	0	0
PSSC	0	0	0	2	3	2
PSSF	0	0	0	0	0	0
PUBF	0	0	0	3	4	3
PUBG	0	0	0	6	9	5
Totals	5	8	5	62	92	55

Natural Features

The Lake Bruce watershed falls along the western most edge of the Northern Lakes Natural Region (Homoya et al, 1985). This Natural Region is comprised of numerous fresh water lakes of glacial origin. Natural community types common to this region include bog, marsh, lake, sedge meadow, prairie and various deciduous forest types. The aquatic communities may be characterized by the presence of bulrush, marsh fern, cattails, pond weeds, spatterdock, Virginia arrow-arum, orchids, tamarack and various species of sedges. The typical forest community which at one time covered over half of this natural region is dominated by oak (chiefly, red oak) and hickory. Other notable species include black, silver, sugar, and red maples; beech; American and red elm; green ash and cottonwood. Distinctive rare and/or endangered fauna of the area include spotted and Blanding's turtles, marsh wren, swamp sparrow and sandhill cranes. State rare and endangered plants reported in the Lake Bruce vicinity include Beck water-marigold Bidens beckii (Figure 59).

Techniques useful in preserving these natural features include:

a. Avoid relocation of natural stream channels

b. Avoid building close to wooded ravines or stream banks.

c. Preserve natural vegetation adjacent to water areas.

d. Avoid construction in, or drainage of, wetlands.

e. Avoid the use of on-site septic systems near the lake or near drainages where there is potential for saturated soils.

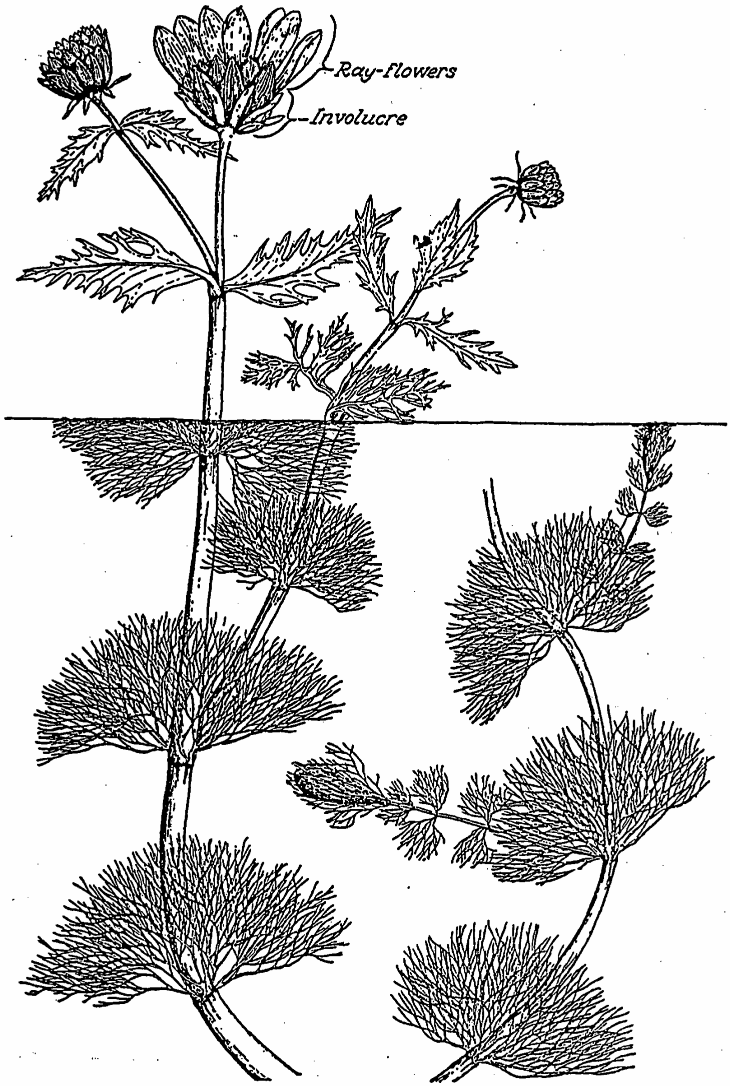


Figure 59. State rare plant taxa reported in the Lake Bruce area, Becks marsh marigold, Bidens beckii. (From Fassett, 1985, p. 321; copywrite 1985, Fassett, reprinted with permission)

Sediment and Nutrient Removal

In order to quantify the effectiveness of a control structure or constructed/enhanced wetland in removing sediments and nutrients, it is first necessary to develop a concept design for the site. Using the conceptual design, a flow model is developed. Flow models are used to determine a particular hydraulic characteristics for a given site at a given point in time. In this case, a flow model would be used to determine the surface loading rate (SLR). The SLR is used to derive the position of a particle (sediment) within a system at a any given point. With this information, a settling time can be predicted for particles entering a system based on distance and time rather than the specific gravity of a select range of particulates. The predicted sediment removal can then be determined by comparing the settling time needed to remove X amount of sediment from a system with the actual retention time for the system. A nutrient budget for the Lake Bruce watershed estimate an annual phosphorous load of 1.2 tons per year and a nitrogen load of 9.8 tons per year, adapted from the 1983 Watershed Protection Plan for Bruce Lake Watershed. Nutrients are removed from a system in two basic ways: 1) by biotic processes in which they are utilized by plants and bacteria or; 2) by physical processes. Nutrients often travel through a system bonded to particulate matter, thus, as sediments are settled out, so are the nutrients attached to them. Sedimentation is the settling out of soil particles which have been transported by air or water. Sedimentation occurs when the velocity of the transport medium (water) is slowed adequately and for a sufficient period of time (detention time) to allow for the soil particles to settle out. Larger heavy particles require high velocities or runoff to be transported and are quick to settle out. Smaller lighter soil particles are transported by suspension or by moving (tumbling) along the surface. Fine silts and clay materials are generally transported in suspension. These smaller soil particles are difficult to recover once eroded. Substantially lower velocities and greater detention times are required to settle these particles out.

Specific site design would be necessary to predict the actual amounts of nutrients transported through a system or to quantify the amount removed by a specific control structure. It is possible, however, to relate nutrient removal efficiencies from other structures designed by Earth Source Inc. At the Wilson Ditch site (near Culver, Indiana) for example, Mean total phosphorous was reduced 90%, while mean total nitrogen (nitrate/nitrite) was reduced 85% during the 1988 summer monitoring program. Mean total phosphorous was reduced 60% and mean total nitrogen was reduced 65% during the 1988 winter monitoring program. Similar nutrient removal rates could be expected for the constructed wetland sites for the Lake Bruce area.

__Computer Modelling__: Overmyer subwatershed

The Overmyer Ditch drains the largest single land area of the Lake Bruce watershed. Annually, it carries the greatest volume of sediment/nutrient ladened water to Lake Bruce. For this reason, the Overmyer Ditch subwatershed was targeted for an indepth study of hydrology and sedimentology. The focus of the study, a computer model using SEDIMOT-II, (Warner, 1983) was used to project storm runoff, hydrographs, and to predicted sediment removal ability of a control structure located on the Overmyer Ditch near Lake Bruce.

The modeling techniques used in the SEDIMOT-II program are divided into four major areas:

1) Rainfall Component. The rainfall component uses a given rainfall depth for a specific storm event, converted into a temporal storm pattern (storm duration over a given geographical area and time) because a large portion of the rainfall may occur over a small period of time with fluctuations in intensity.

2) Runoff Component. The runoff component determines the depth of rainfall in 0.1 hour increments given a 24 hour storm event (TR-55, 1986). The runoff is distributed over a period of time according to predicted rainfall. The runoff component is then used to determine hydrographs at specific locations throughout the watershed.

3) Sediment Component. The sediment component is used to predict sediment production and movement within the watershed and sediment yield at the exit of the watershed or at a specified control structure (Barfield, 1987).

4) Sediment Control Component. The sediment control component is used to predict the performance of a designated control structure at a specific location in the watershed during the specified storm event.

Factors involved in SEDIMOT-II include: storm type, event type, in this case runs were made using rainfall depths from a 2 year and 25 year storm event, soil types, sediment particle size, vegetative cover types, basin relief, drainage area, length of drainage segment, and control structure type. A summary of input data are presented in Appendix F.

The ultimate goal in using the SEDIMOT-II model was to predict the sediment (and sediment bonded nutrients) removal capabilities of constructed wetland-type control structure.

2-Year Storm Event

Data used for the computer model was derived in part from the land use study. Cover types for each segment of the subwatershed were assessed using color infrared aerial photographs, soil input was supplied by the USDA-Soil Conservation Service, and slope segments were determined using information from the US Geological Survey. It was determined that an average 1.5 cubic feet (151 pounds)/acre would be eroded from each acre of the 2889 acre Overmyer subwatershed. The total mass of sediment potentially eroded from the 2889 acre Overmyer subwatershed equals 218.51 tons. SEDIMOT II makes a worst case assumption in this situation, that 100 percent of this material would be delivered to the Control Structure (Figure 60). This obviously does not allow for sediment deposition at toe of slope or other depressional areas throughout the watershed. Therefore, sediment loading values at the Control Structure are seriously exaggerated and Control Structure efficiencies are greatly underestimated. Subsequently, of the 218.51 tons of sediment delivered to the Control Structure from the watershed, 140.14 tons would be removed. This is a predicted efficiency of 64%.
The actual Control Structure efficiency should be comparable if not greater. The actual mean particle size collected would be on the low end (sand-silt-clay) of the sediment distribution, with the larger gravel and soil particles settling out higher in the watershed. The conceptual Control Structure has an area of 44 acres, a storage volume of 33 acre-feet. The 2-year storm event will generate a total runoff volume of 97.65 acre-feet. The detention time for the Control Structure is 41.72 hours at a mean runoff flow of 17 cfs (Figure 61), the results of the 2-year storm event are presented in Table 24.

******************* 2-YEAR STORM EVENT SUMMARY ******************

Storage Area	44.00 acres
Permanent Pool Capacity	33.00 acre-feet
Inflow Runoff Volume	97.65 acre-feet
Peak Inflow Rate	63.12 cfs
Mean Flow Rate	17.00 cfs
Peak Discharge Rate	10.87 cfs
Detention Time of Flow with Sediment	41.72 hours
Detention Time from Hydrograph Centers	26.10 hours
Detention Time Including Stored Flow	39.10 hours
Period of Significant Concentration	66.20 hours
Control Structure Efficiency	>>64.0%

Table 24. **Summary of 2-year storm event results.**
Overmyer Subwatershed.

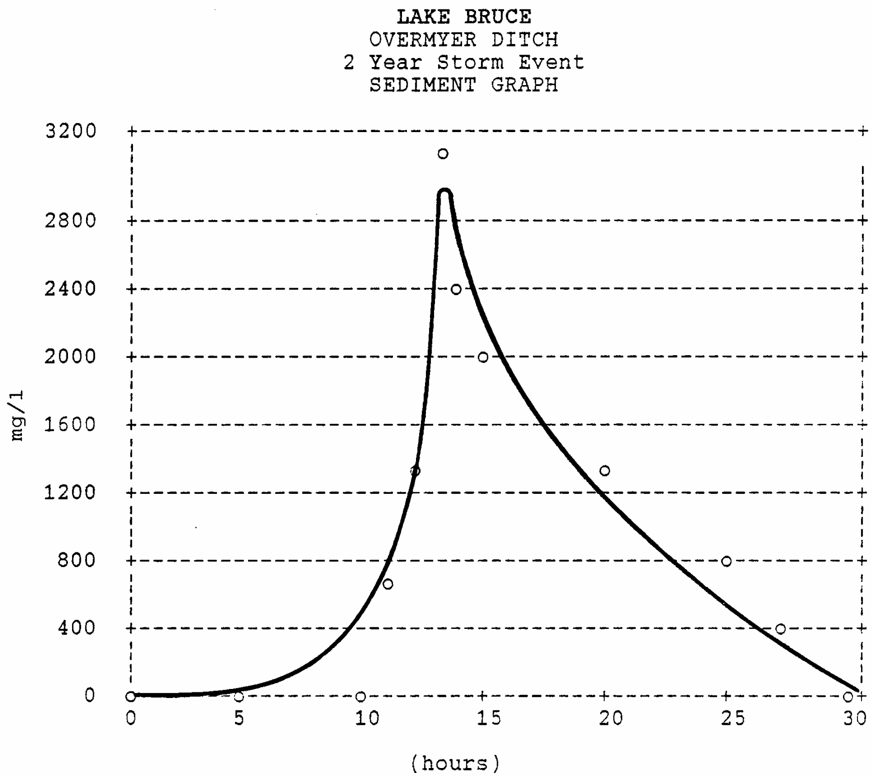


Figure 60. 2-year storm event sediment graph
Overmyer Ditch

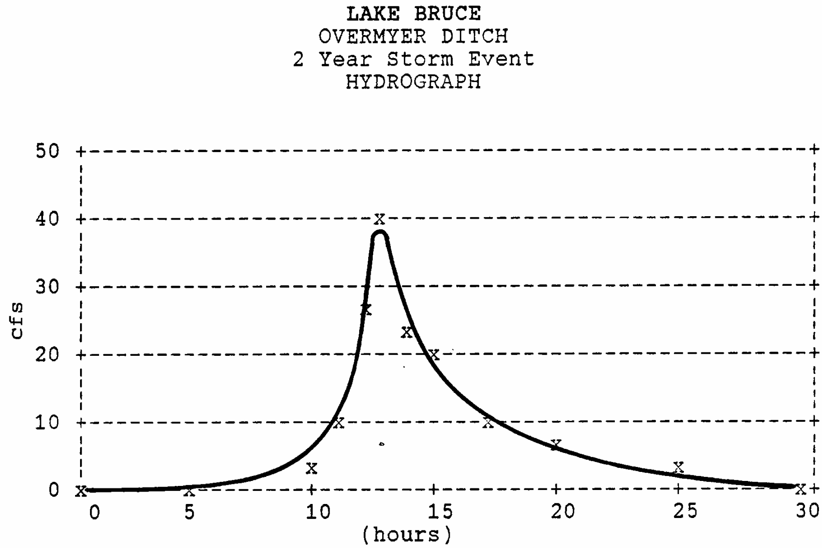


Figure 61. 2-year storm event hydrograph
Overmyer Ditch

25-Storm Event

Uncontrolled erosion is the greatest threat to Lake Bruce from the watershed. This is exemplified in the results of the 25-year storm event model. SEDIMOT-II determined that an average 5.27 cubic feet (527 pounds)/acre would be eroded from each acre of the 2889 acre Overmyer subwatershed (Figure 62). The total mass of sediment potentially eroded from the 2889 acre Overmyer subwatershed equals 761.56 tons. Again, sediment loading values at the Control Structure are seriously exaggerated and Control Structure efficiencies are greatly underestimated. Subsequently, of the 761.56 tons of sediment delivered to the Control Structure from the watershed, 483.95 tons would be removed. This is a predicted efficiency of 63%. The actual Control Structure efficiency should be comparable. The mean particle size collected would in fact be in the mid-range (gravel-sand) of the sediment distribution, with the larger gravel and soil particles predicted by SEDIMOT II, to reach the Control Structure actually removed in the upper reaches of the watershed. The detention time would not be sufficient to remove the smaller silt and clay particles that would make up a large portion of the sediment load carried to the Control Structure. The conceptual Control Structure has an area of 44 acres, and a storage volume of 33 acre-feet. The 25-year storm event will generate a total runoff volume of 294.82 acre-feet. The detention time for the Control Structure is 49.26 hours at a mean runoff flow of 50 cfs (Figure 63), the results of the 25-year storm event are presented in Table 25.

****************** 25-YEAR STORM EVENT SUMMARY ******************

Storage Area	44.00 acres
Permanent Pool Capacity	33.00 acre-feet
Inflow Runoff Volume	294.82 acre-feet
Peak Inflow Rate	201.66 cfs
Mean Flow Rate	50.00 cfs
Peak Discharge Rate	26.13 cfs
Detention Time of Flow with Sediment	49.26 hours
Detention Time from Hydrograph Centers	27.44 hours
Detention Time Including Stored Flow	46.78 hours
Period of Significant Concentration	69.40 hours
Control Structure Efficiency	63.0%

Table 25. Summary of 25-year storm event results. Overmyer Subwatershed.

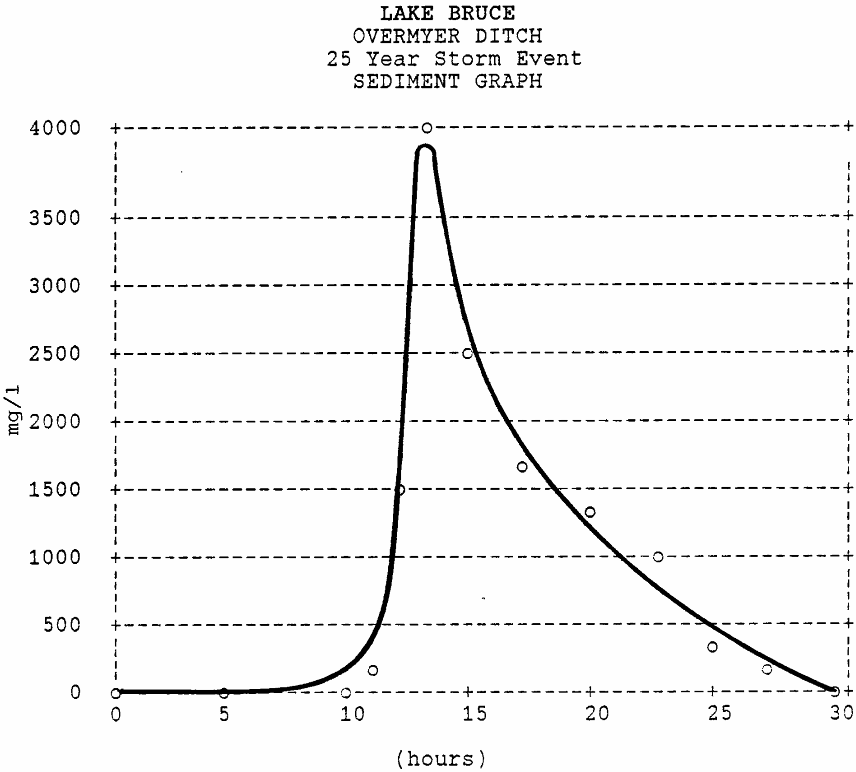


Figure 62. 25-year storm event sediment graph
Overmyer Ditch

LAKE BRUCE
OVERMYER DITCH
25 Year Storm Event
HYDROGRAPH

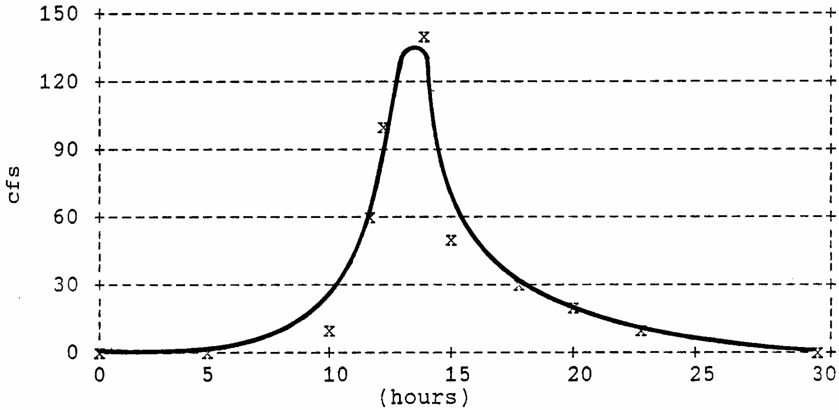


Figure 63. 25-year storm event hydrograph
Overmyer Ditch

Constructed Wetland Habitat

Potential exists for the construction of sediment/nutrient control structures to increase the overall wildlife habitat and production capabilities for the Lake Bruce area.

Primary fisheries production in the Lake Bruce area could benefit greatly by increased wetlands. Virtually all sport fish production is dependent on wetlands, either for spawning, cover or planktonic food production. Pike and sunfishes are major benefactors of increased wetland spawning area. They spawn in the wetlands and then return to the lake proper.

Increased wetlands will draw waterfowl away from areas of moderate human use. Productivity is likely to increase while the "nuisance factor" decreases. Song birds are drawn to wetlands for a number of reasons: nesting structure provided by persistent emergent vegetation (cattails); security cover; and food production. Species such as the Great Blue Heron, Yellow Rail, Great White Egret, and Yellow-headed Blackbird (which are all state threatened, rare or of special concern) will locate near wetlands for many of the same reasons as their avian counter parts.

Fur-bearing animals like beaver, mink and muskrat depend on wetlands primarily for food, security cover and den sizes.

Muskrats will likely be the first fur-bearer to colonize a shallow constructed wetland. These prolific mammals do well in areas which have low water flow and emergent aquatic vegetation such as cattails. If muskrat den/foraging activity strays from or damages the constructed wetland and wetland structures it may become a nuisance, therefore, populations will require careful monitoring.

The mink is one of the most prized furbearers associated with wetlands. The habitat requirements of the mink are similar to those of the muskrat with one exception, the mink is a carnivore. Thus, mink population will usually mirror changes in muskrat population.

The beaver is another valued furbearer likely to colonize a constructed wetland in the Lake Bruce Lake area. Again, if den/dam building activity strays from the constructed wetland it may become a nuisance, therefore, beaver populations will also require careful monitoring.

In summary, a constructed wetland is capable of increasing and supporting a diverse number of habitants. It should be noted that a constructed wetland is also constructed habitat. By design, these areas may attract species of special interest, through planned inclusions of required habitat components.

Constructed Options

For more than 50 years, wetlands have been identified as water purifying systems for natural lakes (van der Valk, et al 1978). Wetland vegetation, benthic organisms, and soils perform as traps, at least seasonally, for nutrients, suspended sediments, metals, pathogens, and many agricultural chemicals (Kadlec and Kadlec 1978). Thus, during the course of the Lake Bruce watershed study, a primary objective was to identify nutrient/sediment trap target sites on each of the contributing ditches. The primary criteria in selecting these sites were: location, topography, flow rates, soils, feasibility, current land use, size, environmental concerns, and sediment/nutrient loading characteristics of the drainage basin (Table 26). For the Lake Bruce study, a 2' contour map of the entire watershed was available, as well as the 1983 Watershed Protection Plan for Bruce Lake Watershed.

Three sites near Lake Bruce have been targeted for constructed options (Figure 64). Site 1 is referred to as the Baker Ditch Site, which drains the southern portion of the watershed, entering the lake at the south end. Site 1 also includes the Bruce Ditch and Bruce tile. Five alternatives are discussed. Site 2 is located on the Overmyer Ditch, which drains the central portion of the watershed, entering the lake on the east side. Site 3 is on the Frasa Ditch, which drains the northern portion of the watershed, entering the lake at the north end. All sites are privately owned, and are on regulated drains. In selecting these sites, the entire lengths of each drainageway were evaluated by the criteria mentioned above. These sites were then evaluated individually. In each case, their close proximity to the lake should produce the most effective results. Large scale constructed alternatives on the upstream reaches of the Overmyer system were generally infeasible, usually ruled out due to flow elevations in the ditch verses the surrounding topography.

Project Descriptions:

Site 1, Baker Ditch, Alternative 1

Intercept the Bruce tile that currently flows into the channel (Figure 65) and route to the Bruce Ditch where it can outlet into an existing wetland complex on the east side of 1100W. Inverts, flow lines, and pipe dimensions would have to be verified for final selection and design of this alternative. Implementation of this project would provide increased filtering of the nutrient rich discharge by way of the `natural areas' on both sides of 1100W.

Site 1, Baker Ditch, Alternative 2

This alternative (Figure 66) would include a sediment trap on the north side of 75N and a site of about 3.8 acres. Due to the flat profile of the Baker Ditch in this area, about 2' of excavation would be necessary over the entire site. An island/baffle type of earthwork is suggested.

This will spread the inflow, and provide some added retention while allowing severe storm events to pass through. If implemented, this project alone could be very effective in treating the inflow from the pumped cropland upstream.

Site 1, Baker Ditch, Alternative 3

This alternative (Figure 67) is simply a baffle that would divert the Baker Ditch flow into the existing marsh north of the railroad grade. This also could be used as an excellent temporary measure until additional aspects of the constructed wetland concept can be implemented.

Site 1, Baker Ditch, Alternative 4

This concept (Figure 68) includes all the aspects of alternatives 1, 2, and 3, and involves additional excavation for island and baffle creation. This could be a very outstanding development from several aspects, in particular, sediment and nutrient trapping efficiency, wildlife habitat, and esthetics. Sensitivity to existing natural features and some private development by the landowners is a must. A shallow perimeter channel would serve for distribution of water. Some shallow excavation will be necessary which can be used to elevate the islands and generate more uniform distribution of flow. About 15 acres would be involved when the entire concept is developed. As part of full development, the sediment load must be addressed on the south side of 75N. This material consists largely of unconsolidated suspended organic material that has been either pumped into the ditch or has been eroded from the ditch bank. A second sediment trap north of 75N should be maintained. Some commitment to the maintenance should be borne by the upstream landowner.

Site 1, Baker Ditch, Alternative 5

This alternative (Figure 69) is construction of a simple filter strip between 75N and the old railroad grade. This would consist of a broadening and re-construction of the channel in a manner that would effect some filtering. The main purpose of this suggestion is to remove pasturing from near the ditch and filter animal lot runoff.

Site 2, Overmyer Ditch

This proposal (Figure 70) is the most ambitious individual project to be considered, as it must be, because of the relatively large contribution to Lake Bruce by this segment of the watershed (as discussed throughout the report). To effect the best results, a large "contact" area is necessary. This means large shallow areas where hydric vegetation can effect nutrient removal as well as sediment and sediment bonded nutrient removal (see Sediment and Nutrient Removal). This site will also intercept sediment from critical erodible lands north of the site. To create the system illustrated would require shallow surface excavation that may average about 1 foot. This material would be for baffles, islands, and low level embankments. A water control device and outfall/emergency spillway structure would be located an more favorable soils near 150N. The design would allow for high flows to go through the site while providing flood storage. Flow arrows are shown in the concept to illustrate how optimum residence time may be achieved. A large portion of the site is mapped on the U.S. Fish and Wildlife Service, Nation Wetland Inventory, which would require permitting of the construction in a wetland under current regulations. This is also significant to the land use and farm operation for this property, since wetlands are regulated and also subject to `Swampbuster' provisions of the 1985 Farm Bill.

Implementation of this site could occur in several phases or "cells" which alone would have some effectiveness. Each inflow would have a sediment basin. This site would have some advantage over the other concepts in that it would more effectively address nutrient removal, is greater in size for increased detention time, has favorable topography, and reduces the potential problems that may occur if water level was raised along 150N.

Site 3, Frasa Ditch

The implementation of this constructed option (Figure 71) will capture an important area of naturally erodible land immediately north and east of the lake. The concept is essentially to close-off the existing open finger ditches with a low level embankment. The area, partially farmed with difficulty, is very flat, so only some minor baffling would be necessary to direct water flow over the site. A perforated riser pipe water control structure may be adequate for the outlet and maintain desired water depths. This site has not been mapped as a wetland by the U.S. Fish and Wildlife Service, Nation Wetland Inventory, although portions of the site appear to be wetland and may require permitting.

It must be noted that constructed wetlands are not a panacea for lake restoration. Constructed wetlands are an effective means of amassing water borne sediment and nutrients, however, constructed options should be pursued in conjunction with limiting sources of sediments and nutrients throughout the watershed. Construction of each of the above sites may benefit by the recommendation for winter drawdown of Lake Bruce, since waterlevels should be lower in the construction sites. This would also positively be an important drainage issue to upstream landowners in that increased winter to spring runoff storage volume may be available in the lake. An asset to both construction and drainage concerns!

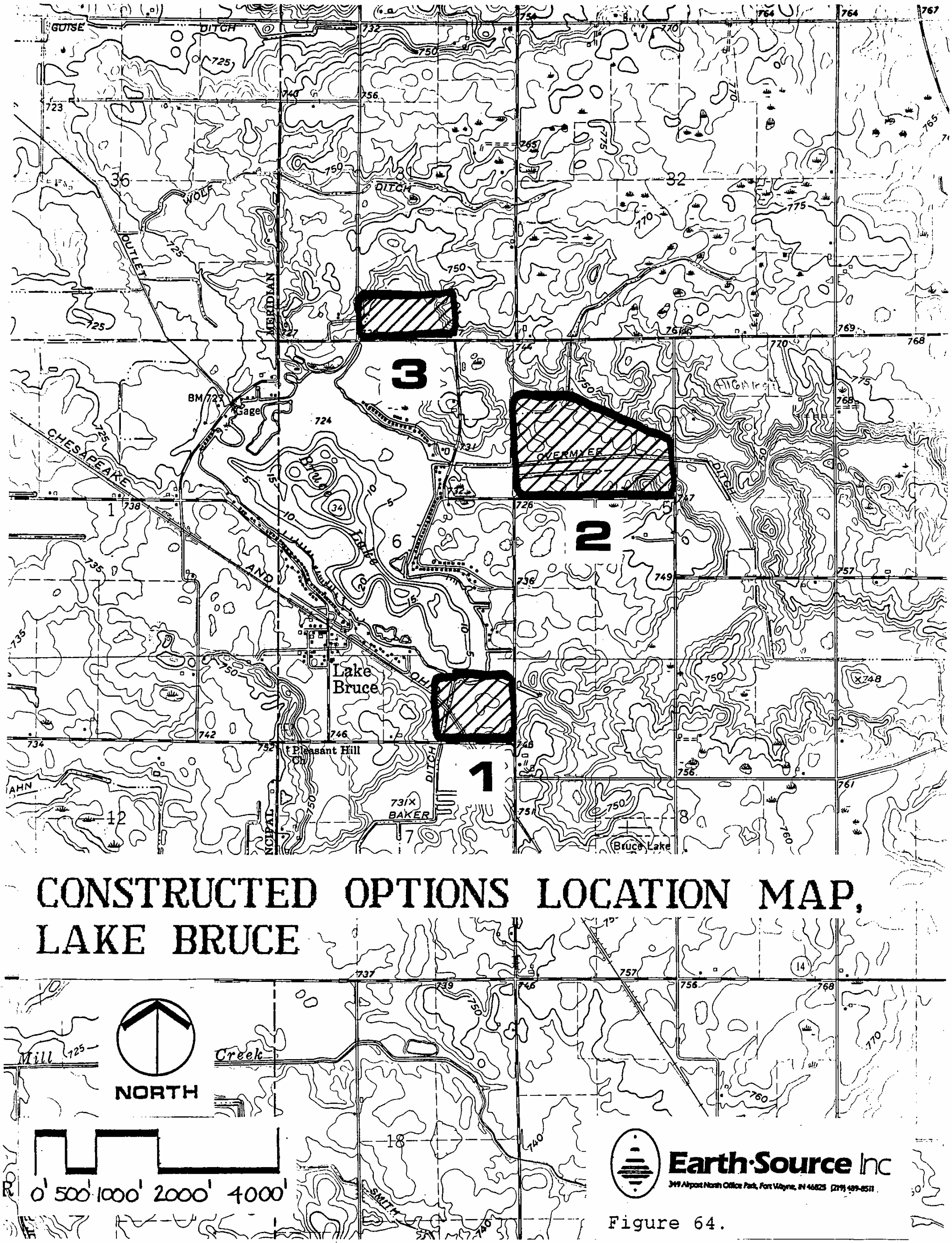
Aside from the many benefits of these proposals in water quality and environmental values, there is the great legacy that these new wetlands will give to their children and their childrens' children.

Table 26. **Water quality data collected from stream monitoring stations (03/23/1989)**.** Streams are listed according to flow (highest to lowest)

MONITORING STATION	TOTAL SUSPENDED SOLIDS (ppm)	TOTAL NITROGEN (ppm)	TOTAL PHOSPHORUS (ppm)
Baker Ditch	6.00	8.27	0.11
Overmyer Ditch*	4.00	9.83	0.08
Frasa Ditch	18.00	11.23	0.10
Bruce Ditch	2.00	8.98	0.09
Bruce Ditch (tile)	1.00	8.17	0.13

* It should be noted that water samples for the Overmyer Ditch were collected near the inlet to Lake Bruce. It is likely that much of the sediments and bonded nutrients would have settled out ahead of the sample point. Therefore the data may be misleading for the reason that in a high flow event, much of the sediments and nutrients would be resuspended and carried into Lake Bruce. For this reason, constructed options for the Overmyer Ditch should be given a high priority.

** The Frasa Ditch was sampled April 4, 1990



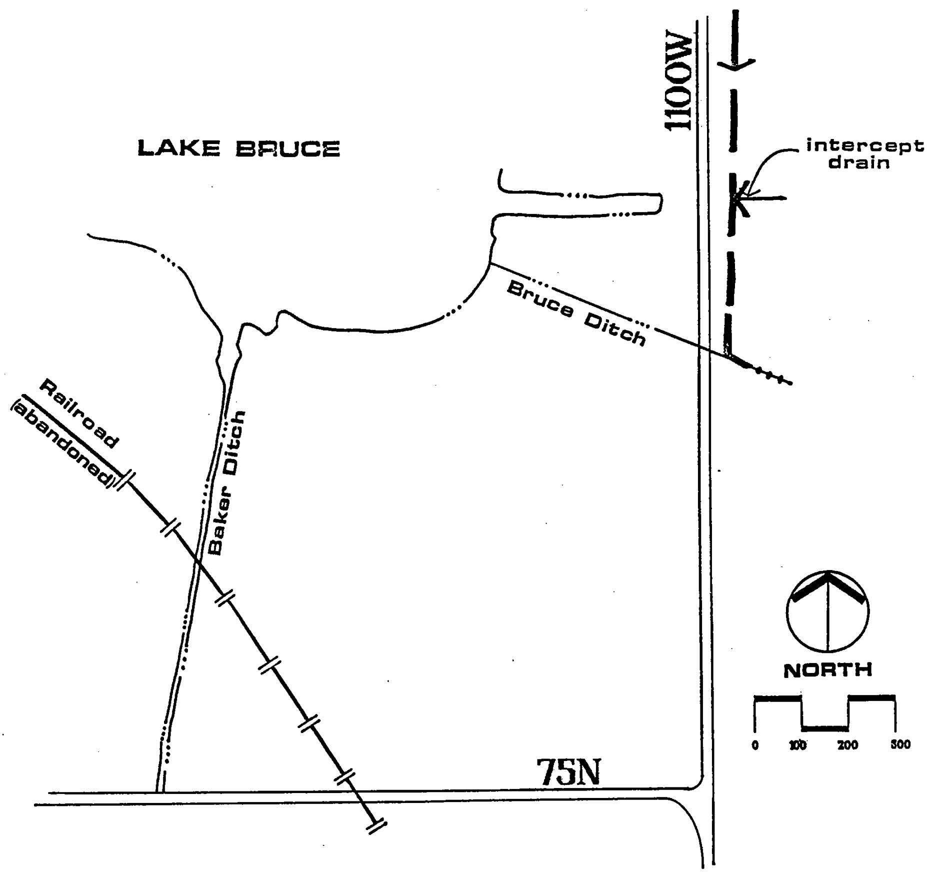
CONSTRUCTED OPTIONS LOCATION MAP, LAKE BRUCE

Figure 64.

SITE 1

ALTERNATIVE 1.

Figure 65.



CONSTRUCTED WETLAND CONCEPT

BAKER DITCH SITE

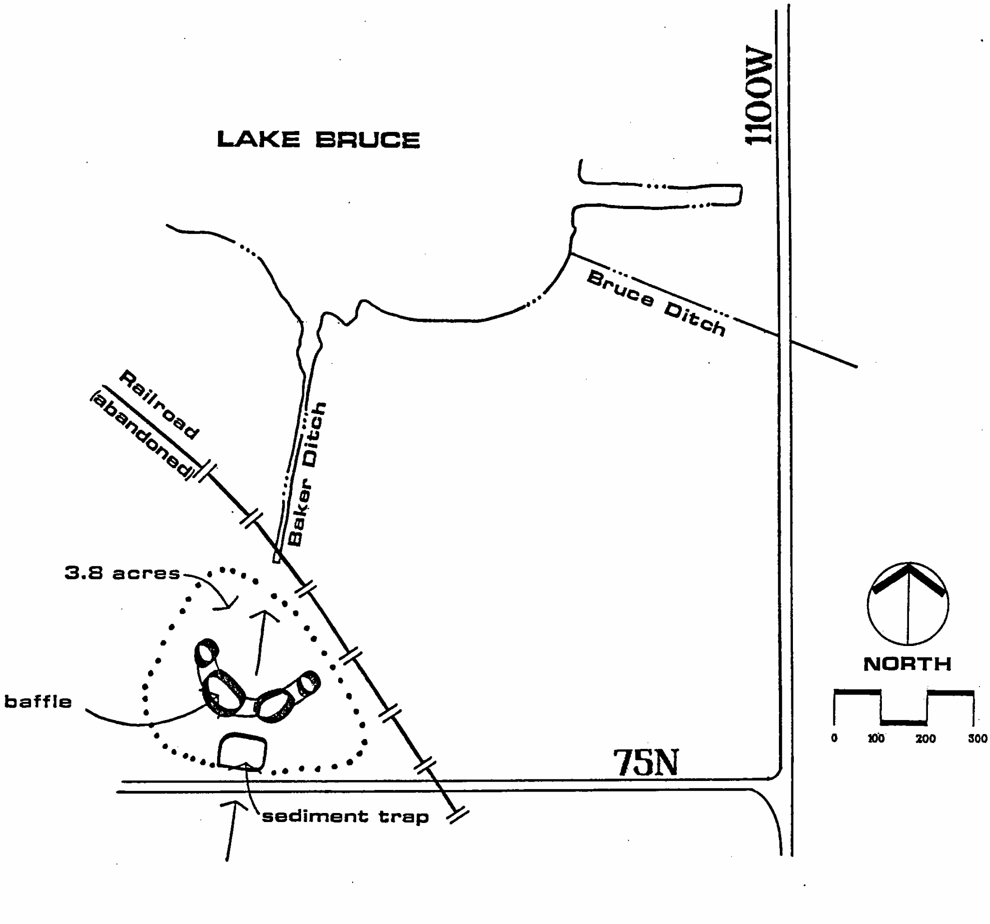
LAKE BRUCE

Earth·Source Inc

SITE 1

ALTERNATIVE 2.

Figure 66.



CONSTRUCTED WETLAND CONCEPT

BAKER DITCH SITE

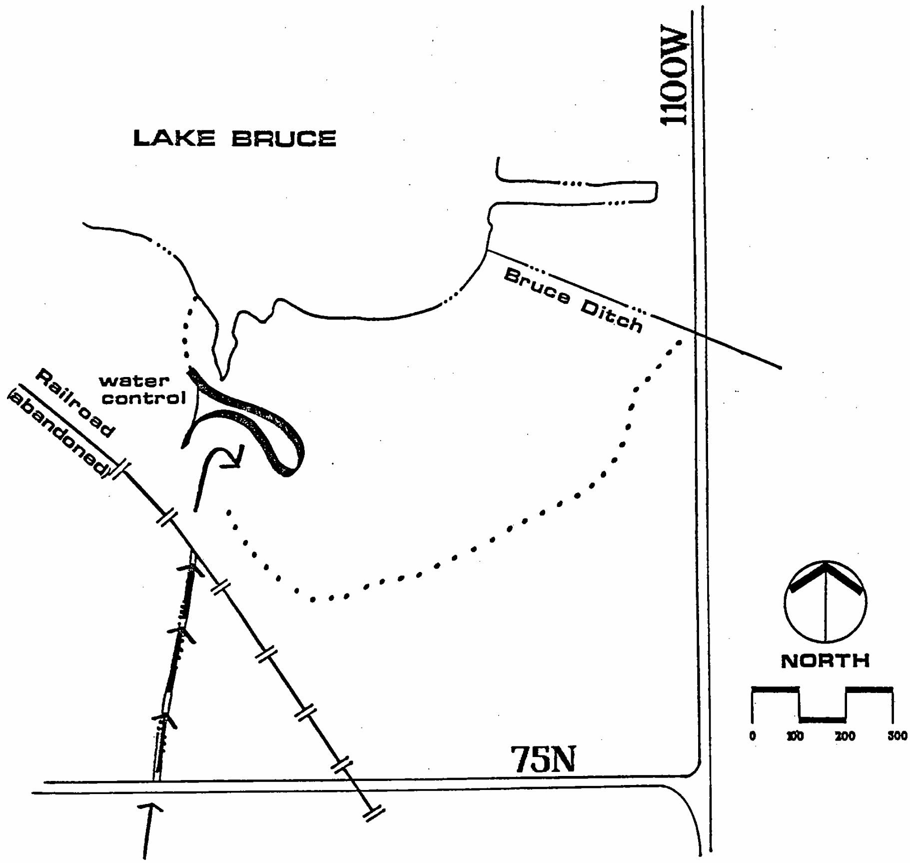
LAKE BRUCE

Earth·Source Inc

SITE 1

ALTERNATIVE 3.

Figure 67.



CONSTRUCTED WETLAND CONCEPT

BAKER DITCH SITE

LAKE BRUCE

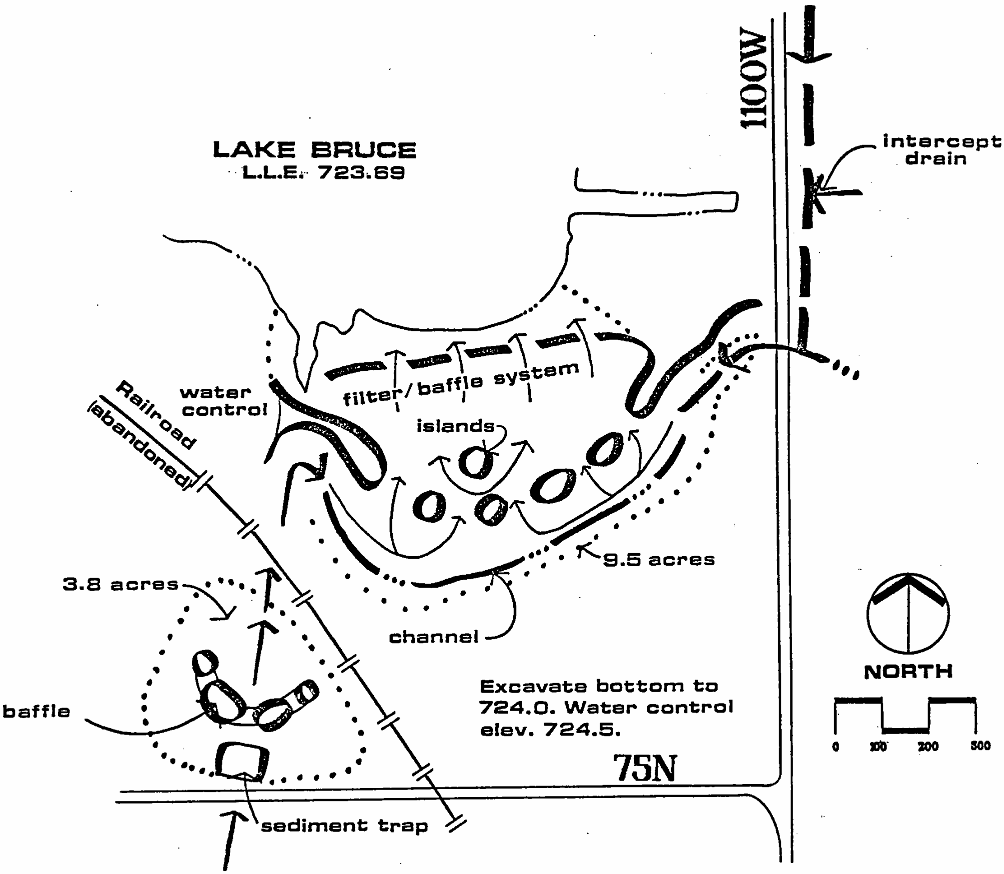
Earth·Source Inc

ITE 1

LTERNATIVE 4.

.gure 68.

Intercept drainage to channel.
Send to constructed wetland.



CONSTRUCTED WETLAND CONCEPT

BAKER DITCH SITE

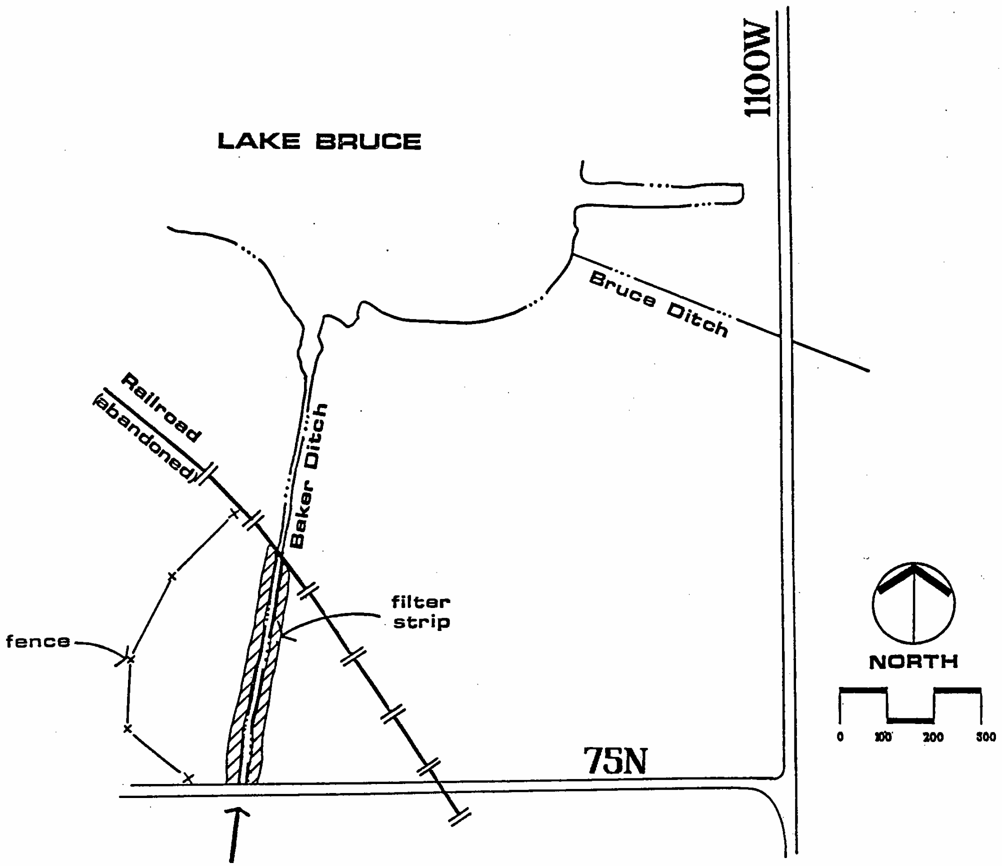
LAKE BRUCE

Earth·Source Inc

SITE 1

LTERNATIVE 5.

igure 69.



CONSTRUCTED WETLAND CONCEPT

BAKER DITCH SITE

LAKE BRUCE

Earth·Source Inc

SITE 2

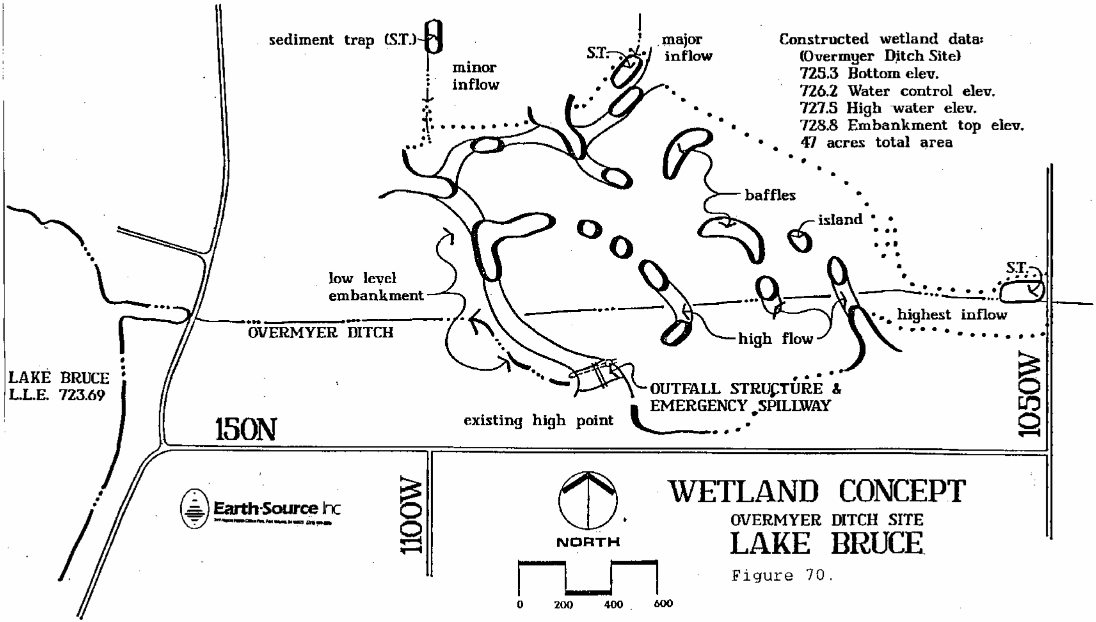


Figure 70.

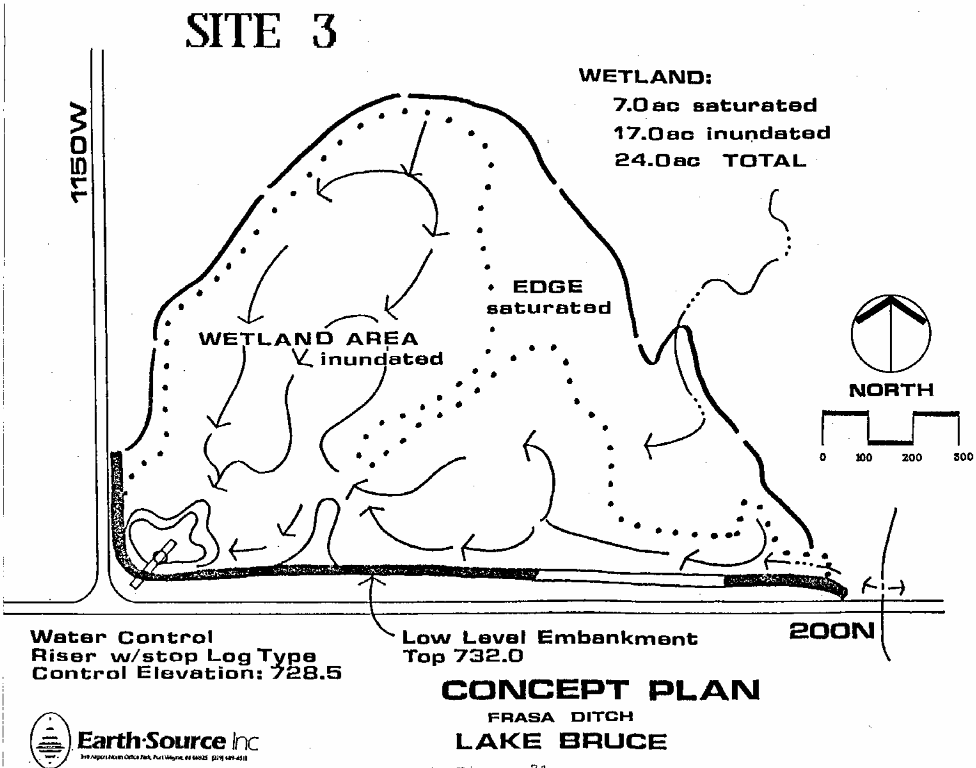

SITE 3
1150W
WETLAND:
7.0ac saturated
17.0ac inundated
24.0ac TOTAL
EDGE
saturated
WETLAND AREA
inundated
NORTH
0
100
200
300
200N
Water Control
Riser w/stop Log Type
Control Elevation: 728.5
Low Level Embankment
Top 732.0
CONCEPT PLAN
FRASA DITCH
LAKE BRUCE
Earth·Source Inc

Figure 71.

Cost Estimates for Constructed Options

The following estimates are offered to represent the anticipated cost factors for construction of suggested sites. During final design, some additional factors may become apparent. To verify existing 2' contour maps or prepare more definitive topography may be necessary and should be part of a proposed design fee. For final design and construction documents, an allowance of 15% to 20% of construction cost should be added to these estimates. Additional cost of services should be added for bidding, construction monitoring and construction administration if these services are required by the funding agencies. Other additional cost items not included in these estimates are as follows:
1. Land cost (if any). 2. Attorney's fees to prepare land agreements. 3. Property line surveys or descriptions.
4. Preparation of permits such as to the Department of the Army, IDNR Division of Water, County Drainage Boards, Indiana Department of Environmental Management. 5. Operation and maintenance of sites and access thereto.

Priority recommendations (Very High, High, Moderate, etc.) have been made based upon the need, doability, availability of the site, and other considerations discussed in construction. The Lake Bruce Association should not be discouraged from pursuing and implementing lower priority constructed options, while higher priority sites are under consideration or in process.

Site 1 **Baker Ditch (Alternative 1)**

Cost items include intercept and relocate section of Bruce tile.
Estimated cost range: $6,000 - 12,000.
Priority recommendation: **Very high**

Site 1 **Baker Ditch (Alternative 2)**

Cost items include sediment trap excavation, excavation of nutrient trap, control structure, erosion control materials, restoration and seeding.
Estimated cost range: $45,000 - 60,000.
Priority recommendation: **Moderate to high**
(coordinate with alternative 4 and 5).

Site 1 **Baker Ditch (Alternative 3)**

Cost items include excavation for construction of baffle, restoration and seeding.
Estimated cost range: $3,500 - 4,500.
Priority recommendation: **High**
(coordinate with alternative 4).

<u>Site 1</u> Baker Ditch (Alternative 4)

Cost items include excavation for two sediment traps, wetland excavation including island and baffle construction, relocation of field tile, distribution channel excavation, pipe water control structure, riprap spillway, wetscape plantings, restoration and seeding.
Estimated cost range: $90,000 - 110,000.
Priority recommendation: **High**
Cost considerations may suggest phasing, e.g. the **preferred alternative** for <u>Site 1</u> may consist of construction of all Site 1 alternatives north of railroad grade <u>first,</u> including alternative 1; then, construction of alternative 5, and/or alternative 2.

<u>Site 1</u> Baker Ditch (Alternative 5)

Cost items include grass filter strips and fence.
Estimated cost range: $3,500 - 4,500.
Add $1,000 for slope dress up grading.
Priority recommendation: **High**

<u>Site 2</u> Overmyer Ditch

Cost items include excavation for three sediment traps, excavation in wetland area (including earthwork for islands, baffles, and embankments), excavation for outlet channel, pipe control structure, riprap spillway, wetscape plantings, restoration and seeding.
Estimated cost range: $150,000 - 220,000.
Priority recommendation: **Highest**
Final design may consider phasing, however, for adequate detention, use of entire site is recommended.

<u>Site 3</u> Frasa Ditch

Cost items include excavation for low level embankment, pipe water control structure, riprap spillway, restoration and seeding.
Estimated cost range: $25,000 - 35,000.
Add $13,000 for excavation in wetland.
Priority recommendation: **High**

Permitting

Beyond property ownership, many governmental agencies may have jurisdiction over private property. For example, drainage may be regulated by the County Surveyor (Table 27). Water issues, particularly construction in a floodway, is regulated by the Indiana Department of Natural Resources Division of Water, and the United States Department of the Army, Corps of Engineers. Excavation below legal lake level (723.69' mean sea level datum) or any ditch modification within .5 miles of Lake Bruce, will require authorization by the IDNR, Division of Water, Lake Section. The Corps of Engineers will require permitting and Water Quality Certification by the IDEM, Office of Water Management for construction in wetland areas. The Corps of Engineers (and the Divisions of Water) may require permitting if any construction impounds water. A list of different agency contacts: addresses and telephone numbers may be found in appendix B.

Table 27. **Regulated county drains of the Lake Bruce watershed.**

Baker Ditch
Overmyer Ditch
Frasa Ditch
Bruce Ditch

Conclusions & Recommendations 3.

CONCLUSIONS AND RECOMMENDATIONS

LAKE BRUCE

Water Quality

Water quality problems were evident at Lake Bruce as early as the first data collection in 1967. Algal blooms were common during midsummer and dominated by blue-green algae. The DNR considered aquatic plants, especially the macroalga Chara, in nearshore areas to be of problem proportions and suggested implementation of a control program. The lake was displaying clear signs of advancing eutrophication.

Eutrophication has continued to advance progressively since at least 1967. Aquatic weeds have continued to expand and to pose problems in nearshore areas as the exotic Eurasian watermilfoil has replaced the native macroalga Chara as the dominant plant in the lake. Although the state eutrophication index decreased from 61 to 33 between 1975 and 1989, it is likely that such a decrease does not indicate an overall improvement in water quality. It is suggested, instead, that this is due to rapid expansion of aquatic weeds and their ability to take up nutrients resulting in lower total phosphorus and greater water clarity in open water areas of the lake during 1989 in spite of no evidence of a reduction in the rate of nutrient loading to the lake from the watershed. Algal blooms dominated by blue-green algae are still common during midsummer, and an algal feeding rough fish characteristic of eutrophic lakes, gizzard shad, increased throughout the 1970's, especially between 1970 and 1973, and now makes up 50-60% of total fish abundance in Lake Bruce.

While both septic and stream drainage have contributed to the eutrophication of Lake Bruce, the latter is likely of greater overall magnitude. Fecal coliform bacteria exceeded state standards on numerous occasions between during the 1960's and dye testing in the 1970's clearly demonstrated direct septic contamination of the lake. Because most of the shoreline residences are located over highly organic and water saturated soils, septic systems are likely not operating efficiently. It is recommended that residents make a concerted effort to have their drain fields inspected regularly and to keep their septic tanks pumped. Residents can reduce nutrient loading to the lake by using phosphate-free detergents for both clothes and dishes. Simple irrigation of lawns using lake water will provide sufficient nutrients to sustain lawn growth. Such simple modification of practices can reduce the contribution each resident makes to the phosphorus and nitrogen loading of the lake.

Water quality improvement in Lake Bruce must address both watershed and in-lake management issues. Implementation of in-lake management practices may provide short term relief from weed problems and other manifestations of eutrophication but will not provide a long term solution without addressing nutrient and sediment imputs to the lake from the watershed. It is suggested that no long term in-lake management solutions be implemented until nutrient and sediment loading from the watershed is reduced dramatically.

Aquatic Weeds

As early as 1967 aquatic weeds were considered to be a problem in Lake Bruce. Chara formed a dense band around the lake at 1-5 feet water depth and was replaced by coontail as the dominant problem plant in water 5-10 feet deep. Weeds were extremely sparse in water greater than 10 feet deep. A chemical control program was initiated in the 1970's that targeted Chara growth in nearshore areas.

Chara was virtually absent by 1989, but aquatic weeds have worsened since the mid 1970's as both chara and coontail have been almost completely replaced by the exotic Eurasian watermilfoil. Currently, weeds choke 80-100% of the water column under 72% of the surface area (93.2 acres) of Lake Bruce. Weed problems are principally restricted to water depths less than 5-10 feet with 84% of the 0-5 foot contour being choked with weeds. Most stands of problem aquatic weeds are less than 2 feet tall.

A number of techniques can be implemented to control problem weeds (Crisman 1986, Moore and Thornton 1988). Excessive growth can be cut mechanically and removed from the lake. Although this reduces plant biomass and possibly nutrients, this is no permanent solution because roots and seeds are left intact, and finding a suitable site for disposal of the cut material is often difficult. Residents could continue the chemical control program as in previous years. This is merely a stop gap measure that can do more harm than good. Nutrients released from decaying vegetation enter the water column and can promote phytoplankton blooms. Numerous cases exist of excessive chemical treatment that shifts lakes to algal dominance and a whole new range of management problems.

Given that weed problems are restricted mostly to water less than 5 feet deep, it is proposed that the outlet dam be modified to permit a lowering of water level by 5 feet during winter. Such drawdowns can freeze weed roots, hinder germination of seeds, and oxidize and compact organic nearshore sediments. Although some plant species may be resistant to drawdowns and may actually increase afterward, the major problem plant taxa in Lake Bruce (Eurasian watermilfoil and coontail) can be controlled by this management technique (Moore and Thornton 1988).

There are some potential negative effects of drawdown that should be examined. Algal blooms could occur as a result of nutrient release from plant tissue. As discussed earlier, plants compete with algae for nutrients and removal of macrophytes can free nutrients for algal utilization. Oxidation of sediments and plant matter can also lead to winter fish kills due to reduction of oxygen during decomposition if the period of ice cover is especially long. Fish populations can also be affected through alteration of benthic invertebrate communities and loss of plant cover as protection from predators. The latter fish effects are not considered likely at Lake Bruce given the fact that the plant cover is so extensive that such areas are little utilized by fish. It is strongly recommended that any drawdowns be coordinated with the district fishery biologist from the Division of Fish and Wildlife, DNR.

Drawdown at Lake Bruce could be a reasonably simple process. Removable boards in the dam could be taken out during early fall to drop water level during winter and be replaced and locked before early spring rains. In this way flood protection would not be compromised, and the lake would be at its current legal limit in time for summer recreational activities. Following initial dam modifications, continued weed control would be cost free. The precident for establishing a modified winter legal water level has already been established for at least one lake in northern Indiana (Sylvan), where a series of winter drawdowns were performed during the late 1970's and early 1980's.

Any weed control at Lake Bruce must be approached cautiously. Without reducing nutrient loading to the lake from the watershed and possibly the lake sediments, algal blooms may replace weed problems. The problem of nutrient recycling from lake sediments could pose the greatest problem in the eastern half of the north basin, a shallow area currently completely colonized by macrophytes. Removal of macrophytes would expose sediments to wave action and possibly result in increased internal nutrient cycling. If sediment nutrient release proves to be a problem, then nutrient inactivation or bottom sealing should be considered as management options. The best way to insure that algal problems do not follow macrophyte problems is to avoid overly zealous complete control of macrophytes in the lake.

Fish

The DNR fish survey of 1967 noted that although bluegill and largemouth bass populations were low, their growth and fitness were considered excellent but that removal of excessive weed growth in nearshore areas would likely improve populations. Gizzard shad populations expanded markedly between 1970 and 1973 prompting DNR to suggest that a selective eradication program be implemented. A selective shad kill using antimycin was employed in 1974, but this proved ineffective at long term reduction of shad importance in the lake. Since 1976 rough fish, especially shad, have been the dominant fish in the lake both on a numerical and weight basis. The high biomass of shad is particularly alarming and is taken as a sign of advancing eutrophication. Shad feed heavily on algae and once in lake systems can promote dominance by blue-green species due to their inefficient digestive system.

Fish stocking has been undertaken at least twice at Lake Bruce. Following the 1974 selective eradication, 19,265 largemouth bass were stocked, and 8,483 northern pike were introduced in 1978 as predators on shad.

A majority of the fish in Lake Bruce (40%) are restricted to water depths of 4-5 feet during midsummer due to serious oxygen depletion in deeper waters. It is likely that attempts at fishery management will be only marginally successful until nutrient loading to the lake is reduced significantly. Overall, the DNR has done an excellent job managing the Lake Bruce fishery in spite of severe limitations in both funding and manpower. It is recommended that lake residents encourage the State of Indiana to provide additional funding support for the type of service offered by the DNR.

Basin Infilling

Ditches and culverts have contributed significant nutrient and sediment loadings to Lake Bruce. Unlike comparably eutrophic Indiana lakes, the sediments of Lake Bruce are highly inorganic indicating the extreme importance of watershed derived sediments in lake infilling. Much of the phosphorus loading to the lake likely is from watershed sources and delivered concurrently with the inorganic sediment, but heavy metal and herbicide/pesticide contamination of sediments from watershed sources was not observed in Lake Bruce.

Lake Bruce has displayed a great degree of infilling during the past 34 years. All five-foot depth contours less than 10 feet deep increased in aerial extent between 1955 and 1989 with the greatest percentage increase (44%) being displayed by the 5-10 foot interval. Basin infilling was greatest in the northern portion of the north basin and the southern portion of the south basin. The volume of Lake Bruce has been reduced approximately 25% since 1955. It is obvious that a majority of the sedimentation in the lake is directly related to stream input of watershed sediment especially during spring rain events.

It is recommended that particular attention be paid to reducing the loading of nutrients and sediments by ditches and culverts. In addition to watershed control measures to be discussed later, aquatic weeds at the mouths of ditches should be left intact as a nutrient and sedimentation barrier. Removal of such plant growth will speed delivery of both parameters into the lake thus accelerating both basin infilling and eutrophication.

If drawdown is used as a management option for aquatic macrophytes as discussed above, submergent weeds in front of inlet stream mouths will also be destroyed. It is recommended that a mixed species assemblage of emergent plant species be planted at stream mouths to serve as a nutrient and sediment trap. Cattails, for example, would likely be little affected by periodic winter drawdowns (Moore and Thornton 1988).

As it has also been demonstrated that nearshore erosion via wave action has contributed also to basin infilling, it is recommended that homeowners be encouraged to leave a fringe of emergent vegetation along the entire length of their lake front to serve as an erosion barrier. Homeowners should also inspect their shoreline for evidence of erosion and make appropriate repairs immediately. Finally, boaters should be encouraged to reduce speed when near shore in order to minimize wave generation and subsequent erosion of shoreline areas.

The Watershed

Conclusions and Recommendations.

It is apparent that nutrient and sediment loading from the Lake Bruce watershed has not decreased over recent history. It is also apparent that the lake has met the increased availability of nutrients by the tremendous expansion of submergent macrophytes. Successful aquatic weed control is dependent on curtailing the flow of nutrients and sediment bonded nutrients to the lake from the watershed. For this reason, priority should be given to one or more of the major constructed options and/or land treatment of critical erosion areas, prior to any significant aquatic weed control program including lake drawdown. Allowing aquatic weeds to persist until one or more of the major constructed options is in operation will also serve to remove excess nutrients stored in the lake system.

I. General recommendations:

Encourage preservation of remaining upland forest, wetlands and upland depressions.

Avoid relocation of natural stream channels.

Avoid building close to wooded ravines or stream banks.

Preserve natural vegetation adjacent to water areas, such as remaining in lake wetlands at stream inflows. The north shore near the Frasa Ditch inlet still has some good lake edge that should be preserved. The extreme south end also has some good wetland shore areas that also should be preserved.

Avoid construction in, or drainage of, wetlands.

Maintain natural vegetative cover wherever possible.

Stabilize drainage areas immediately following any construction or "maintenance". Quick vegetative cover and streambank protection is essential to erosion control.

II. Lake Residents:

Residents must take on the responsibility of maintaining their own waste disposal systems. Drain fields should be inspected regularly and septic tanks should be pumped on a regular schedule.

Avoid the use of on-site septic systems near the lake or near drainages where there is potential for saturated soils.

Consider engaging an engineering study for a lake-wide sanitary sewer district that considers several alternative methods of wastewater disposal.
If fertilization for lakefront lawns is desired, residents should consider using irrigation of lawns using lake water.

A setback from the lake should be required for all future building and total sediment control measures should be used.

Construct and maintain sediment control structures such as erosion control mats and straw bale filters, **prior** to construction of any lake or waterfront development.

Stabilize drainage areas immediately following any construction or "maintenance".

III. **The Watershed:**

Continue to encourage minimum and no-till farming practices in the upland portion of the watershed. Other land treatment practices, especially stream/ditch bank stabilization, should be pursued. This could be accomplished by establishing grassed ditch borders (filter strips), and, in more extreme cases, structural or riprapped solutions. Excavate and maintain sediment traps that may be located at easily accessible intervals, such as near roads. (Other various Conservation Practices are listed in Appendix C. These practices will be detailed in individual farm Conservation Plans, as required by the 1985 Farm Bill to be implemented by 1995).

Consider other Constructed Options as described in that Section of this report: a) intercept and divert the Bruce tile. b) construct nutrient/sediment trapping systems on: Baker Ditch, Frasa Ditch, & Overmyer Ditch.

Those areas defined as HEL/severe slope areas should maintain natural buffer areas or filter strips along streams and ditches. Every effort should be made to enlist those lands into CRP or related land treatment programs. The Fulton County SCS has made excellent strides towards protecting some HEL adjacent to the Overmyer Ditch.

Stabilize stream bank or ditch escarpments.

A monitoring program should be implemented in upstream segments of the Overmyer Ditch. Upstream monitoring would more precisely locate sediment and nutrient loading zones of the watershed. Once identified, management practices could be implemented.

Samples should be analyzed for total phosphorus, ortho-phosphorus, total nitrogen, nitrate/nitrite, total suspended solids, coliform and streptococcal bacteria.

Protect sloping areas. Vegetation is difficult to establish and maintain on eroded slopes.

Row cropping should be done perpendicular to slope. Break up long slope lengths by multiple cropping or landscaping when natural cover is not maintained. Divert runoff from severely sloping areas.

Get cattle out of the ditches and ditch banks, perhaps, by helping landowners find financial assistance to fence and construct filter strips. Also, Filter strip or otherwise intercept runoff from animal feedlots.

Utilize sediment ponds below feed lots and "open" sloping lands.

Avoid spreading manure during the winter or near direct drainageways unless it can be incorporated IMMEDIATELY.

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Appendix

APPENDIX A

SYSTEM: R — RIVERINE

SUBSYSTEM: 1 — TIDAL; 2 — LOWER PERENNIAL; 3 — UPPER PERENNIAL; 4 — INTERMITTENT; 5 — UNKNOWN PERENNIAL

CLASS	Subclass
RB — ROCK	1 Bedrock 2 Rubble
UB — UNCONSOLIDATED BOTTOM	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic
*SB — STREAMBED	1 Bedrock 2 Rubble 3 Cobble-Gravel 4 Sand 5 Mud 6 Organic 7 Vegetated
AB — AQUATIC BED	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular 5 *Unknown Submergent* 6 *Unknown Surface*
RS — ROCKY SHORE	1 Bedrock 2 Rubble
US — UNCONSOLIDATED SHORE	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated
**EM — EMERGENT	2 Nonpersistent
OW — *OPEN WATER/ Unknown Bottom*	

*STREAMBED is limited to TIDAL and INTERMITTENT SUBSYSTEMS, and comprises the only CLASS in the INTERMITTENT SUBSYSTEM.

**EMERGENT is limited to TIDAL and LOWER PERENNIAL SUBSYSTEMS. The remaining CLASSES are found in all SUBSYSTEMS.

SYSTEM: P — PALUSTRINE

CLASS	Subclass
RB — ROCK BOTTOM	1 Bedrock 2 Rubble
UB — UNCONSOLIDATED BOTTOM	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic
AB — AQUATIC BED	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular 5 *Unknown Submergent* 6 *Unknown Surface*
US — UNCONSOLIDATED SHORE	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated
ML — MOSS-LICHEN	1 Moss 2 Lichen
EM — EMERGENT	1 Persistent 2 Nonpersistent
SS — SCRUB-SHRUB	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead 6 *Deciduous* 7 *Evergreen*
FO — FORESTED	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead 6 *Deciduous* 7 *Evergreen*
OW — *OPEN WATER/ Unknown Bottom*	

SYSTEM: L — LACUSTRINE

SUBSYSTEM: 1 — LIMNETIC

CLASS	Subclass
RB — ROCK BOTTOM	1 Bedrock 2 Rubble
UB — UNCONSOLIDATED BOTTOM	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic
AB — AQUATIC BED	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular 5 *Unknown Submergent* 6 *Unknown Surface*
OW — *OPEN WATER/ Unknown Bottom*	

SUBSYSTEM: 2 — LITTORAL

CLASS	Subclass
RB — ROCK BOTTOM	1 Bedrock 2 Rubble
UB — UNCONSOLIDATED BOTTOM	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic
AB — AQUATIC BED	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular 5 *Unknown Submergent* 6 *Unknown Surface*
RS — ROCKY SHORE	1 Bedrock 2 Rubble
US — UNCONSOLIDATED SHORE	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated
EM — EMERGENT	2 Nonpersistent
OW — *OPEN WATER/ Unknown Bottom*	

MODIFIERS

In order to more adequately describe wetland and deepwater habitats one or more of the water regime, water chemistry, soil, or special modifiers may be applied at the class or lower level in the hierarchy. The farmed modifier may also be applied to the ecological system.

WATER REGIME

Non-Tidal

- A Temporarily Flooded
- B Saturated
- C Seasonally Flooded
- D *Seasonally Flooded/ Well Drained*
- E *Seasonally Flooded/ Saturated*
- F Semipermanently Flooded
- G Intermittently Exposed
- H Permanently Flooded
- J Intermittently Flooded
- K Artificially Flooded
- W Intermittently Flooded/Temporary
- Y Saturated/Semipermanent/ Seasonal
- Z Intermittently Exposed/ Permanent
- U *Unknown*

Tidal

- K *Artificially Flooded*
- L Subtidal
- M Irregularly Exposed
- N Regularly Flooded
- P Irregularly Flooded
- *S Temporary-Tidal
- *R Seasonal-Tidal
- *T Semipermanent-Tidal
- *V Permanent-Tidal
- U *Unknown*

*These water regimes are only used in tidally influenced, freshwater systems.

WATER CHEMISTRY

Coastal Halinity

- 1 Hyperhaline
- 2 Euhaline
- 3 Mixohaline *(Brackish)*
- 4 Polyhaline
- 5 Mesohaline
- 6 Oligohaline
- 0 Fresh

Inland Salinity

- 7 Hypersaline
- 8 Eusaline
- 9 Mixosaline
- 0 Fresh

pH Modifiers for all Fresh Water

- a Acid
- t Circumneutral
- i Alkaline

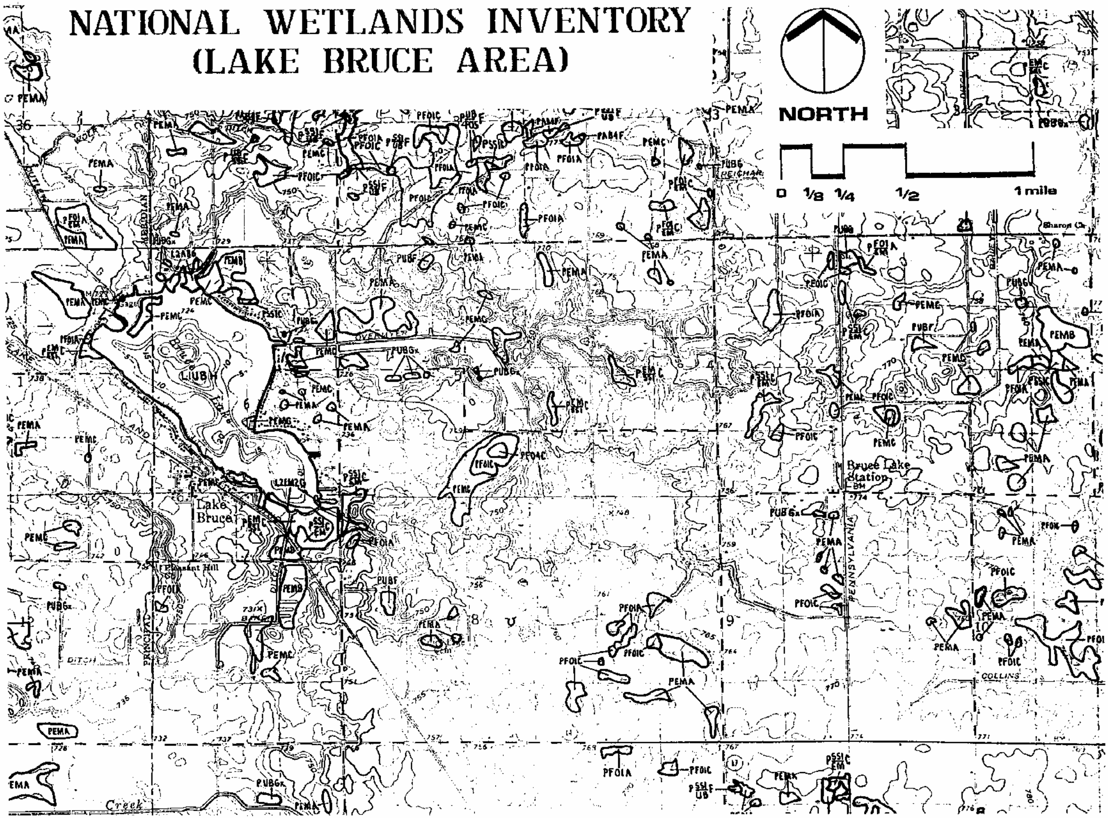
SOIL

- g Organic
- n Mineral

SPECIAL MODIFIERS

- b *Beaver*
- d *Partially Drained/Ditched*
- f Farmed
- h *Diked/Impounded*
- r Artificial Substrate
- s *Spoil*
- x Excavated

NATIONAL WETLANDS INVENTORY (LAKE BRUCE AREA)



APPENDIX B

The following is a list of Federal, State and local agency contacts which may be useful in obtaining further information or permit requirements.

EPA
Wetland Protection Section
401 M Street SW
Washington, D.C. 20460
(202) 382-5043

EPA, Region V
230 S. Dearborn Street
Chicago, IL 60604
(312) 353-2079

US Army Corps of Engineers
20 Massachusetts Ave., NW
Washington, D.C. 20314
(202) 272-0169

US Army Corps of Engineers
Detroit District
P.O. Box 1027
Detroit, MI 48231
(313) 226-6773

US Fish & Wildlife Service
18th & C Streets, NW
Washington, D.C. 20240
(202) 343-4646

US Fish & Wildlife Service
Bloomington Field Office
718 N. Walnut Street
Bloomington, IN 47401
(812) 334-4267

IDNR
Division of Water
2475 Directors Row
Indianapolis, IN 46241
(317) 232-4160

IDEM
Office of Water Management
Chesapeake Building
105 South Meridian Street
Indianapolis, IN 46206
(317) 232-8476

IDNR
Div. of Soil Conservation
FLX1 Building
Purdue University
West Lafayette, IN 47907
(317) 494-8383

IDNR
Div. of Fish & Wildlife
607 State Office Building
Indianapolis, IN 46204
(317) 232-4080

Fulton County Surveyor
Courthouse
Rochester, IN 46975
(219) 223-3317

USDA-SCS, Fulton County
Baker Building
513 Main Street
Rochester, IN 46975
(219) 223-3220

Pulaski County Surveyor
Courthouse
Winimac, IN 46996
(219) 946-3253

USDA-SCS, Pulaski County
436 North West Street
Winimac, IN 46996
(219) 946-3023

Earth Source Inc. (consultant)
349 Airport North Office Park
Fort Wayne, IN 46825
(219) 489-8511

APPENDIX C

Various Conservation Practices and Values, and Degree of Difficulty for Implementation

Conservation Plans	Required by the 1985 Farm Bill
Land Adequately Treated	Normal
Conservation Cropping System	Difficult
Critical Area Planting	Moderately Difficult
Crop Residue Management	Difficult
Diversions	Difficult
Farmstead Windbreak	Normal
Feedlot Windbreak	Normal
Field Windbreak	Normal
Field Border	Very Difficult
Grade Stabilization	Moderately Difficult
Grassed Waterway	Difficult
Holding Ponds & Tanks	Easy
Livestock Exclusion	Moderately Difficult
Livestock Watering Facility	Moderately Difficult
Minimum Tillage	Difficult
Pasture & Hayland Management	Difficult
Pasture & Hayland Planting	Difficult
Pond	Easy
Recreation Area Improvement	Normal
Sediment Control Basin	Difficult
Stream Channel Stabilization	Moderately to Very Difficult
Streambank Protection	Moderately Difficult
Stripcropping	Very Difficult
Surface Drains	Difficult
Terraces, Gradient	Very Difficult
Terraces, Parallel	Very Difficult
Tile Drains	Difficult
Tree Plantings	Very Difficult
Wildlife Habitat Management	Moderately Difficult
Woodland Harvesting	Moderately Difficult
Woodland Improvement	Difficult

Adapted from Final Report on the Black Creek Project; Allen County (Indiana) Soil and Water Conservation District.

APPENDIX D

PRACTICE	EFFECTIVENESS	LONGEVITY	CONFIDENCE	APPLICABILITY	POTENTIAL NEGATIVE IMPACTS	CAPITAL COST	O&M COST
Addition of Tertiary Treatment	E	E	E	E	E	F	F
Construction of Sedimentation Basins at Inlets to Lake	G	E	G	G	G	F	F
AGRICULTURAL PRACTICES							
—Conservation Village	F-E	G	G	G	F	F	F
—Contour Farming	F-G	P	F	G	E	E	E
—Pasture Management	F-G	E	E	G	E	E	E
—Crop Rotation	F-G	G	G	G	E	E	E
—Terraces	F-G	G	G	G	E	F	G
—Animal Waste Management	E	E	E	E	E	F	F
—Grass Waterways	E	E	G	G	E	G	E
—Buffer Strips	E	E	E	E	E	G	E
—Diversion of Runoff	G	G	F-G	F	E	F	G
CONSTRUCTION CONTROLS							
—Erosion Control Ordinance	E	E	E	E	E	E	E
—Runoff Control Oridnance	E	E	E	E	E	E	E
—Field Inspections	E	E	E	E	E	E	E

Legend: E = Excellent G = Good F = Fair P = Poor

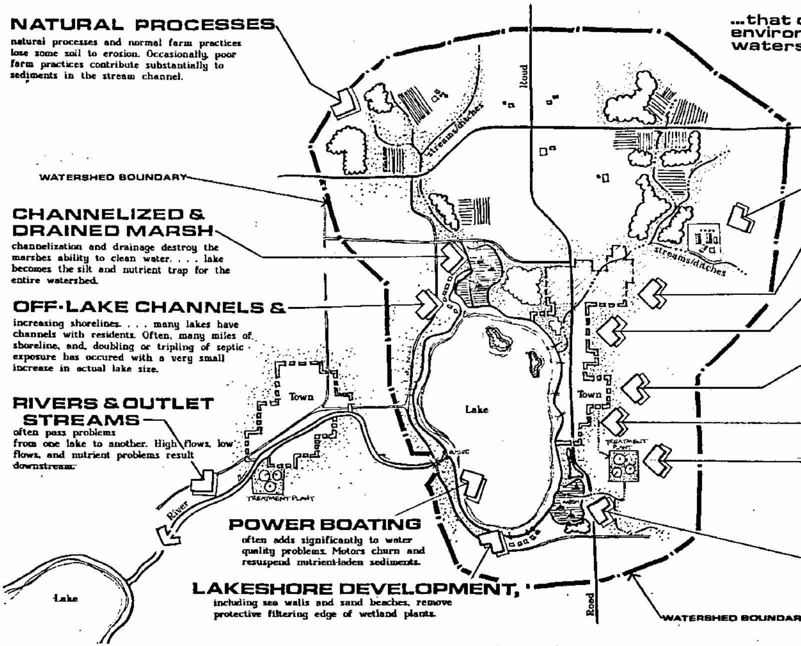
SOURCE: The Lake and Reservoir Restoration Guidance Manual, USEPA

APPENDIX E

TYPICAL SEDIMENT/ NUTRIENT SOURCES...

...that contribute to decline of environmental values in a watershed.

Earth·Source Inc



NATURAL PROCESSES

natural processes and normal farm practices lose some soil to erosion. Occasionally, poor farm practices contribute substantially to sediments in the stream channel.

CHANNELIZED & DRAINED MARSH

channelization and drainage destroy the marshes ability to clean water. . . . lake becomes the silt and nutrient trap for the entire watershed.

OFF-LAKE CHANNELS &

increasing shorelines. . . . many lakes have channels with residents. Often, many miles of shoreline, and, doubling or tripling of septic exposure has occured with a very small increase in actual lake size.

RIVERS & OUTLET STREAMS

often pass problems from one lake to another. High flows, low flows, and nutrient problems result downstream.

POWER BOATING

often adds significantly to water quality problems. Motors churn and resuspend nutrient-laden sediments.

LAKESHORE DEVELOPMENT,

including sea walls and sand beaches, remove protective filtering edge of wetland plants.

LARGE ANIMAL

operations often exist immediately on inlet streams. This can contribute a very significant negative to water quality.

FACTORIES

may have inadequate safety storage which may result in spills into streams.

PAVED PARKING & STREETS

drain directly into lake or stream, bringing soil, salt, debris, oil and chemical spills.

FERTILIZERS & CHEMICALS;

(both lawn and agricultural) drain and leach into lakes.

COMBINATION SEWERS...

old systems overflow into streams and lakes.

EFFLUENT

may be inadequately treated and is discharged into stream, which carries the problem into the lake or outlet to pass problem downstream.

MARSHES

often occur on inlet streams. These are often considered eyesores to the lake, when, in reality, they are probably the lakes most valuable asset!!

APPENDIX F

INPUT PARAMETERS FOR SEDIMOT-II

HYDROLOGY DATA

STORM TYPE:	SCS TYPE II
RAINFRALL DEPTH:	2.70 INCHES (2-YEAR)
	4.50 INCHES (25-YEAR)
STORM DURATION:	24.00 HOURS
TIME INCREMENT:	0.10 HOURS
HYDROLOGIC SOIL GROUP:	B/C
LAND USE:	RUNOFF CURVE NUMBER:
AGRICULTURE -ACTIVE	71-88
AGRICULTURE -OTHER	72-81
FORESTED	55-73
PASTURELAND	49-61
RESIDENTIAL	74
WETLAND	30

SEDIMENTOLOGY DATA MODIFIED UNIVERSAL SOIL LOSS EQUATION

DELTA G:	1.60-2.65
LOAD COEFFICIENT:	1.50 (DEFAULT)
SUBMERGED BULK SPECIFIC GRAVITY:	1.25 (DEFAULT)
SOIL ERODIBILITY FACTOR:	.17-.28
RAINFALL EROSITIVITY FACTOR:	127.29 EI UNIT
CONTROL PRACTICE FACTOR:	.08
PARTICLE DISTRIBUTION:	SIZE (mm):
1	10.0000
2	5.0000
3	2.0000
4	1.0000
5	0.5000
6	0.0500
7	0.0100
8	0.0050
9	0.0010
10	0.0005
11	0.0001

STRUCTURAL DATA

MANNING'S ROUGHNESS COEFFICIENT:	0.016
GRASS HEIGHT:	48.00 INCHES
AVERAGE SPACING BETWEEN STEMS:	0.56 INCHES
INFILTRATION RATE:	0.05 INCHES/HOUR
GRASS STIFFNESS FACTOR:	200.00 N-M SQ
GRASS FILTER AREA:	3.79 ACRES (TWO STAGE)
GRASS FILTER SLOPE:	0.25%
POND SURFACE AREA:	28.00 ACRES (TWO STAGE)
TOTAL STORAGE CAPACITY:	46.90 ACRE-FEET
OUTFALL WITHDRAWAL:	SURFACE